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THE PRESENT STATUS OF AIR-SHIPS IN EUROPE.*

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I. GENERAL.

DURING the past three years aëronautics has developed from the field of invention into that of engineering. Air-craft are no longer invented out of pure speculation, but are designed according to engineering principles from the formulæ of the research laboratory and the data of the testing laboratory. A type is only new in the matter of the application of well-known principles, and is in the nature of an improvement and perfection of existing types. The requirements of military and naval authorities and the conditions of prize contests have created a demand for an engineer to design air-craft to meet given specifications. There has thus evolved a new technician, the aëronautical engineer. The air-craft of 1913 are principally to be distinguished by the evidence of engineering skill in their design and construction.

Recognition by the public of the value of air-craft in national defence has led to the development of an industry devoted to the supply of dirigibles and aëroplanes. Especially in France and Germany has aëronautics been stimulated in this manner. France developed the first practical dirigibles, but has until recently con-

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centrated her energy chiefly upon aëroplanes, with the result that at the present time the French army is estimated to have between 500 and 1000 aëroplanes in service. These aëroplanes are, moreover, of types that represent the highest development in aëroplane design. On the other hand, Germany, realizing the menace of this aërial force and the impossibility of duplicating it, has recognized the possibilities of the dirigible and given liberal support to the development of the ships of Count Zeppelin and Major von Parseval. Great sums have been spent and many lives have been lost, but the reward has already come. The German army now possesses a splendid fleet of 25 air-ships, representing the highest development in air-ship design. At the same time, France has brought her fleet of air-ships up to 18, and Germany has some 200 military aëroplanes with a large civilian reserve. It has become a race for the supremacy of the air between two great powers whose capitals lie within the radius of action of air-craft from each other.

England has recently joined the race for supremacy, and, apparently realizing that it is too late to overtake her continental rivals by the mere multiplying of units, has directed every effort toward the development of air-craft superior in design to the existing types. Foreign machines have been purchased liberally, and an aërodynamic laboratory and an experimental air-craft factory have been built. England's future in aëronautics is placed in the hands of an Advisory Committee headed by Lord Rayleigh and composed of distinguished scientists and engineers. The race then is not only between the factories but also between the laboratories. The production of a type of marked superiority will immediately make obsolete the aërial forces of other powers.

This rivalry between the great military powers is a most fortunate thing for the art, for in no other way could such intense interest in its problems be created. In laboratories, shipyards, and factories able men are working to improve the safety and reliability of aërial transportation with a devotion and intelligence that must lead to substantial advance in the general utility of air-craft.

II. DIRIGIBLES.

Dirigible balloons are self-propelled air-ships in which the lifting force is given by a gas-filled envelope beneath which cars are suspended for the accommodation of the power plant and passengers. In the rigid type the envelope is held in shape by a

rigid frame. In the non-rigid type the envelope is held in shape by internal gas pressure. A third type, the semi-rigid, seeks to provide a rigid frame only about the lower part of the envelope. The relative merits of these types can best be discussed after considering their qualities more in detail.

French Dirigibles.

The non-rigid dirigible was developed in France, between 1885 and 1900, by Renard, Krebs, Juillot, and Santos-Dumont, and has followed closely the improvement of the gasoline motor. At the present time ships of the non-rigid type are being built by the Astra Society (M. Surcouf), Zodiac, Clement Bayard, Lebaudy, and Godart. One wood-framed rigid Speiss dirigible is building at the Zodiac works.

Astra Dirigible (Fig. 1).

The Astra Society, of which the engineer E. Surcouf is director, has recently purchased the Torrés patents and is building ships of remarkable speed and elegance of design.

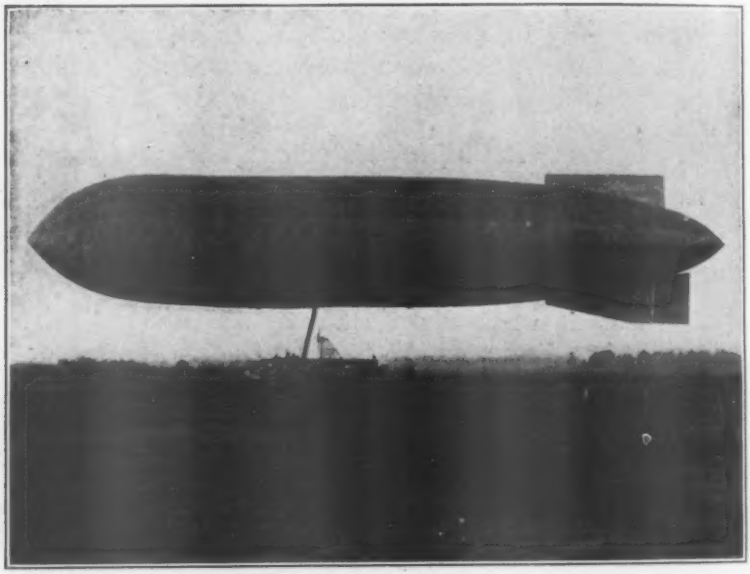
Envelope.—The envelope built on the Torrés system consists of three lobes in which the indentations or cusps run longitudinally. It has the appearance in general of a cucumber or an elongated cantaloupe. The internal gas pressure fills out the lobes, which have their cusps tied together by internal rope rigging. The ropes are, therefore, always in tension. Longitudinally, heavy ropes run from bow to stern along the inside of the cusps. The result is a long girder all of whose parts are in tension. The longitudinal strength so given the envelope makes it possible to moor such a ship to a post in the open by means of a cable from the nose. There is, of course, the extra weight of internal rigging over the envelope of ordinary fish-shaped form, and the lobed cross-section presents more surface per given volume than a circular section. However, the heavy belly-band and external rigging between car and envelope are avoided in the Astra-Torrés type and considerable head resistance saved. Furthermore, the total weight of the car comes upon the internal rope rigging and does not tend to strain the envelope. The envelope can then be made of lighter material than in the ordinary type. There is an additional advantage claimed from the fact that in any envelope subject to internal pressure the stress in the fabric varies as the radius of curvature at any point. The radius of

curvature is less in a lobed cross-section than in a circular one for a given total area of section.

Suspension.—The car is suspended below the envelope by vertical steel cables. The use of external rigging and crow's feet is entirely avoided, as the weight is taken directly by the interior rope girder and thence distributed to the envelope.

Car.—The car can be made very short without causing the back of the envelope to sag. The weight is evenly distributed by the internal roping. The car is covered with fabric or sheet metal.

FIG. 1.



Astra-Torrés non-rigid dirigible.

Its framing is an elastic structure of steel tubing easily taken apart for shipment or stowage aboard ship.

Motors.—Water-cooled motors of various commercial types have been employed. Usually two units are installed for the sake of reliability. In view of the elastic nature of the car, it is not considered necessary by the builders to mount the motors on springs.

Propellers.—Either or both motors may drive either or both propellers through proper clutches, reverse clutches, and gearing. Two wooden propellers are carried on brackets of steel tubing projecting upward and outward from the car. The propeller axis

is raised so that the centre of thrust may come nearer the centre of head resistance, and so that when the car is on the ground the whirling blades are no menace to the heads of bystanders.

Gas Pressure.—Hydrogen gas 15 mm. above atmospheric pressure fills the envelope. It may be noted here that hydrogen is now used in all air-ships. A lifting force of 1.12 kg. per cubic metre of gas 99 per cent. pure may be counted on.

Swivelling Axis.—The propeller axes are mounted in such a manner that they may be movable in a vertical plane parallel to the centre line of the ship. This is of assistance near the ground and in manœuvring.

Stability.—Static stability is given as in all air-ships by having the centre of gravity below the centre of buoyancy. The usual methods of naval architecture may be applied to the calculation of stability. Stability of route is given by the envelope form fitted with a vertical fin aft. The centre of side resistance is thus placed abaft the centre of gravity. The ship is steered by horizontal and vertical rudders on the after part of the envelope. Equilibrium in altitude is adjusted by the use of water ballast and a relief gas valve. The practice in free ballooning is followed. In descending from a high altitude, gas must be allowed to escape in order to reduce the lift. As the ship descends the gas pressure of 15 mm. is kept constant by inflating internal air-sacs or ballonets. The ballonets are connected by a duct of fabric to a blower in the car operated by the motors, or by hand in an emergency.

The following particulars of the naval type Astra-Torrés purchased by the British Admiralty are given as illustrative:

TYPE, ASTRA-TORRÉS XIV, SCOUT.

Volume in cubic metres	7500
Speed, kilometres per hour	82.2
Length, metres	75
Height, metres	21
Diameter, metres	14
Useful lift, kilos	2500
Crew	5
Radius of action in hours	12
Ballast, kilos	315
Cars	1
Propellers	2
Power, horsepower	400

This ship made a speed 51.1 miles per hour on her acceptance test, the world's record for dirigibles.

The company has under construction two ships of 24,000 metres cube in which it is expected 12 men may be carried 20 hours at over 80 kilometres per hour. Four 250-horsepower motors will drive four propellers.

Zodiac Dirigible.—The Zodiac Company builds non-rigid dirigibles in which the envelope is a solid of revolution below which the car is suspended. A heavy canvas belly-band is sewed to the bottom of the envelope. From toggles in this band hemp crow's feet lead to wire rope rigging attached to the car. In order to distribute the load uniformly to the envelope, the car is made long and narrow.

The horizontal rudder for control of elevation is mounted on the forward part of the car. In this position the rudder throws no force on the flexible tail of the envelope and also gives considerable lift by its aëroplane effect. The ship can thus be caused to ascend without loss of ballast.

The following details are given of their latest ship:

TYPE, FLEURUS AMÉLIORÉ.

Volume, cubic metres	14,000	
Speed, kilometres per hour	79	
Length, metres	100	
Diameters, metres	16	
Crew	12	
Radius of action, hours	20	
Cars	1	of length 26 m.
Propellers	3	
Motors	3	Zodiacs.
Power, horsepower	675	
Altitude, metres	1,800	

In case of a forced landing without assistance an anchor with 150 metres of line can be thrown out to hold the ship head to wind.

Two machine guns are mounted on the car and one on a platform on the top of the envelope, reached by a ladder running through a trunk in the envelope.

Clement Bayard (Fig. 2).

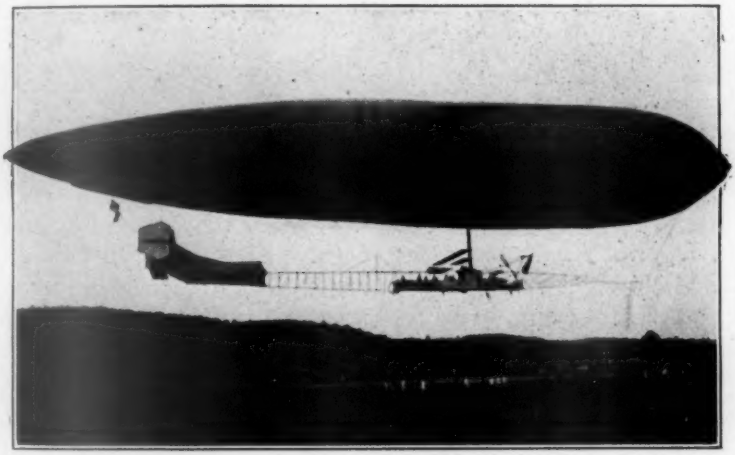
Dirigibles built by this firm have the benefit of the resources of one of the greatest automobile plants in France. Their situa-

tion industrially is interesting, and well worth considering by American firms contemplating air-craft manufacture. In the Clement Bayard factory, when air-ship building is slack, the skilled and experienced mechanics are absorbed in other departments of the works as machinists, erectors, upholsterers, etc.

The principal features of Clement Bayard ships are:

(1) Variable pitch propellers for reversing or changing speed. It is considered that the propellers can be worked at high efficiency, both at full and half power, by properly adjusting the pitch.

FIG. 2.



Clement Bayard non-rigid dirigible.

(2) A vertical lifting propeller of variable reversing pitch absorbs some 50 horsepower from a shaft geared to the main motors. This propeller is used in getting away from the ground, or to check downward velocity in landing. It is in many ways a simple substitute for swivelling propeller axes.

(3) An aëroplane surface over the centre of gravity of the car can be moved in inclination by the pilot. The lift of this plane assists in climbing.

The French army possesses three large Clement Bayard airships, besides the "Adjutant Vincenot" and "Deputy de Lôme."

The following details are given of a scout type supplied to the French army.

TYPE, SCOUT.

Volume, cubic metres	6,500
Speed, kilometres per hour	60
Length, metres	73.5
Diameter, metres	12.2
Fabric	Double diagonal, rubberized.
Radius, hours	15
Cars	1, length 10 m., width 1.8 m.
Propellers	2 variable pitch for propulsion. 1 variable pitch for ascension.
Motors	2 Clement Bayard on springs.
Power, horsepower	180
Altitude, metres	2,000
Ballonet volume, metres cube	2,400
Blowers	2

Self-starter on motors. Sand ballast.

German Dirigibles.

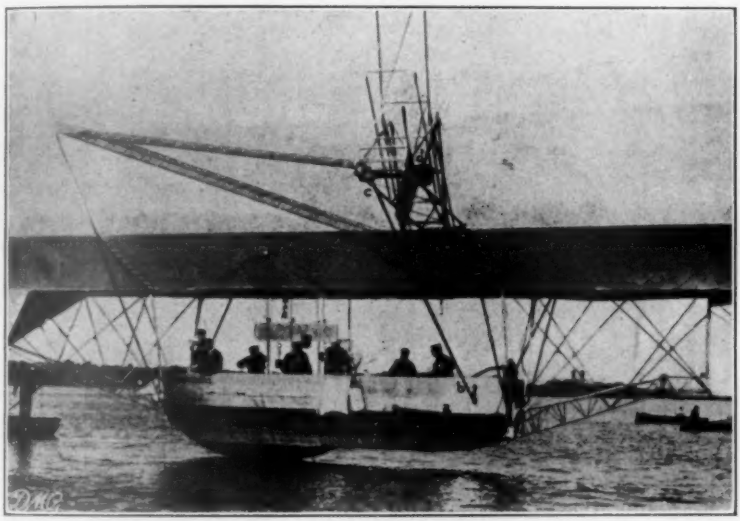
Zeppelin Rigid Dirigibles (Figs. 3, 4, 5, 6).—In Germany the development of air-ships has been greatly encouraged by the attitude of the army. The Zeppelin Company, manufacturing the rigid type Zeppelin dirigible at Friedrichshafen, as well as the Delag company operating passenger Zeppelins, have been heavily subsidized. In return for such financial support these companies are pledged to secrecy as to the construction of the ships.

It is likely, however, that the construction is in no way mysterious and is based on sound engineering practice and a great deal of experience gained from long and costly experiment, great failures, and appalling accidents. The essential feature is an aluminum alloy for the frame which is both light and tough. Naturally the composition of this alloy is kept secret.

The hull of the Zeppelin ships consists of a long frame of aluminum alloy bars and steel wires made up of longitudinal members tied together at intervals by some 18 to 20 wheel-like transverse partitions. In each of the sections so formed a gas bag of gold-beater's-skin is enclosed. The whole is enclosed in a linen waterproof non-gastight cover stretched over the frames. Each gas bag is fitted with a relief valve, spring loaded, or oper-

ated from the pilot's stand in the forward car. Gold-beater's-skin is found to be more impervious to hydrogen than any other material used to date. It is, however, low in tensile strength and can only be used to advantage on the dirigible air-ship when the gas is only slightly above atmospheric pressure. In the non-rigid ships the form is preserved by the inner pressure and rubberized fabric must be used. The hydrogen leakage in such case is about one per cent. in 24 hours under the best conditions, and is frequently greater.

FIG. 3.



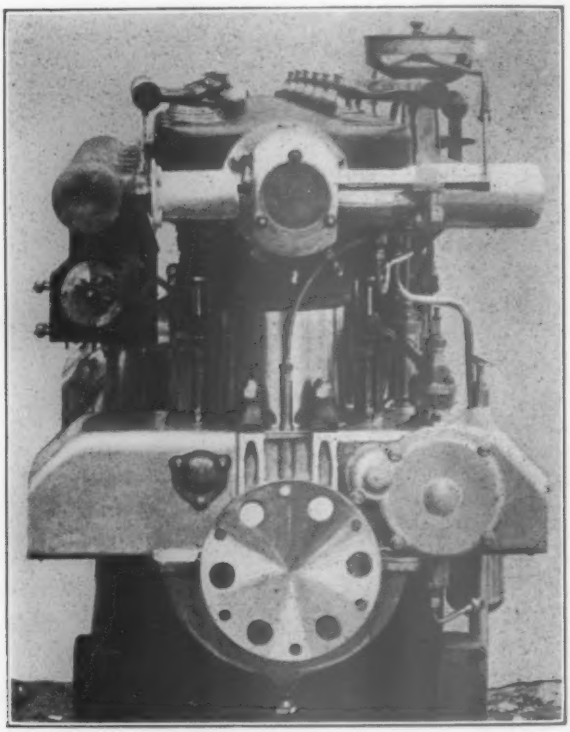
Forward gondola of Zeppelin.

Cars or gondolas are secured beneath the hull of the Zeppelin dirigible forward and aft. These cars are rigidly attached to the overhead framing and are very close to the envelope to diminish head resistance. There is also a middle car for the accommodation of passengers, armament, or freight. The power plant is carried in the forward and after cars.

The *motors,* three or four in number, are of special design for reliability and smooth running. All Zeppelins are now equipped with Maybach motors made by a subsidiary company. These motors have recently been put on the market and are used by the

Parseval air-ships. They are made in 200- and 300-horsepower units, 6 cylinders, water-cooled, double Bosch low-tension ignition, forced lubrication; 1100 to 1300 revolutions per minute; material special alloy steels; gasoline consumption .228 kilogramme per horsepower hour, oil consumption, .015 kilogramme per horsepower hour; weight of 200-horsepower motor,

FIG. 5.

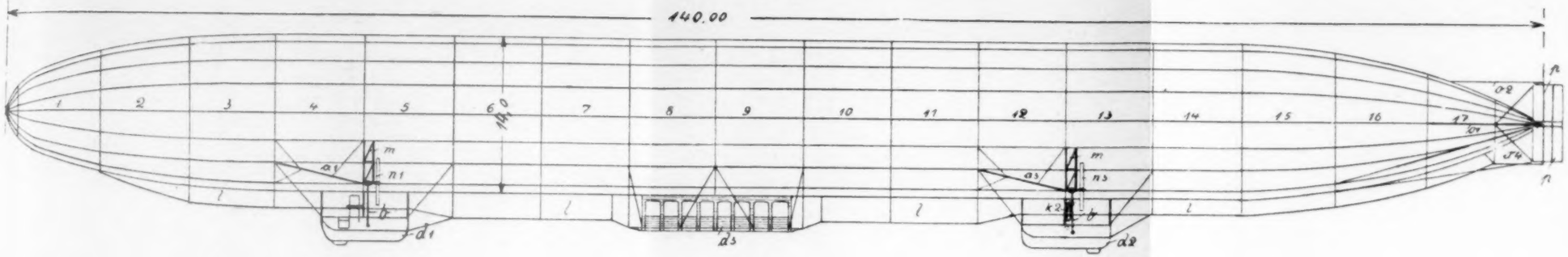


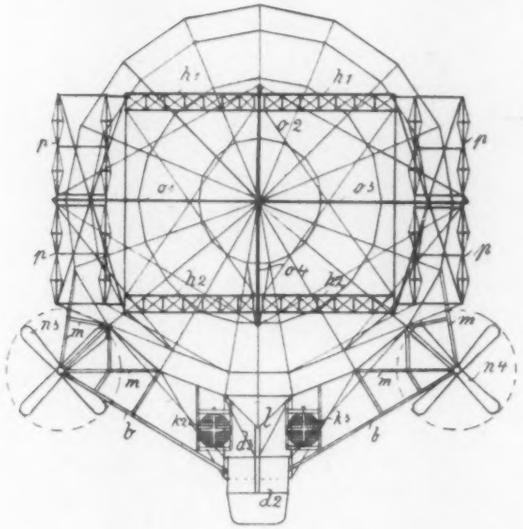
Maybach motor.

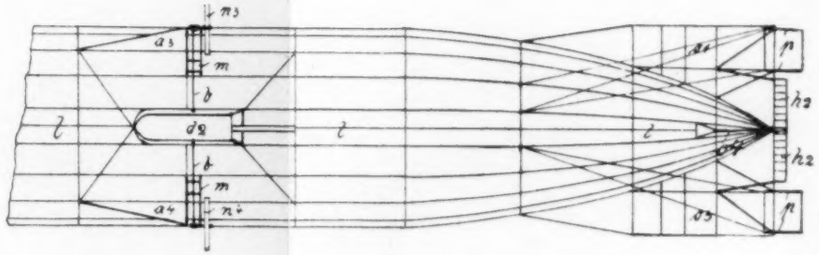
with cooling and ignition systems, 425 kilogrammes. These motors, on account of their even running, need not be mounted on springs. They operate well at reduced power, but usually when it is desired to reduce power one motor is stopped and the other worked full power.

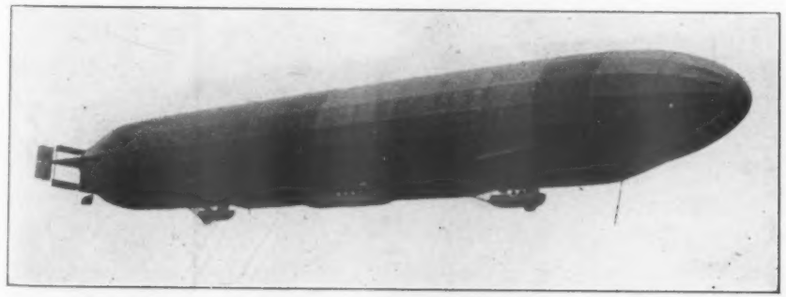
Control.—The ship is steered by horizontal and vertical rud-

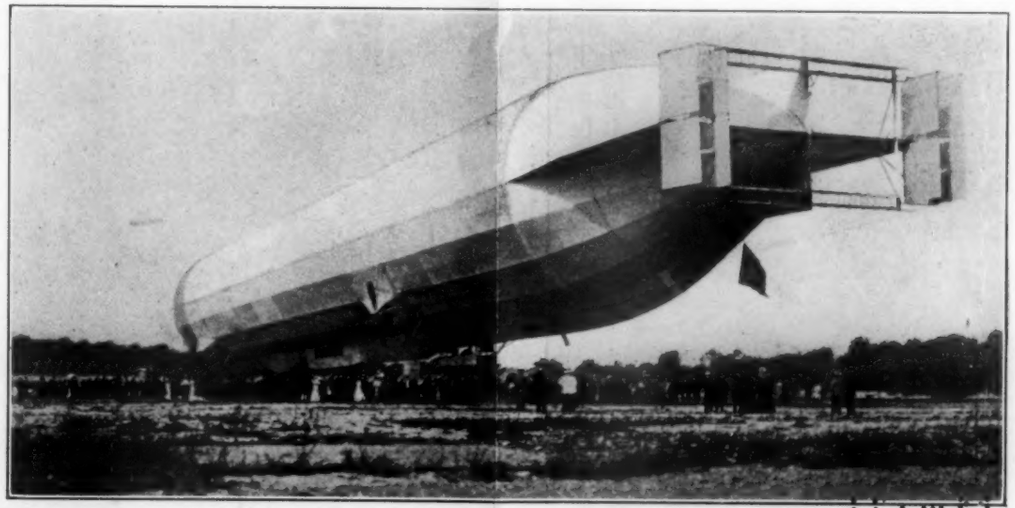
FIG. 4.







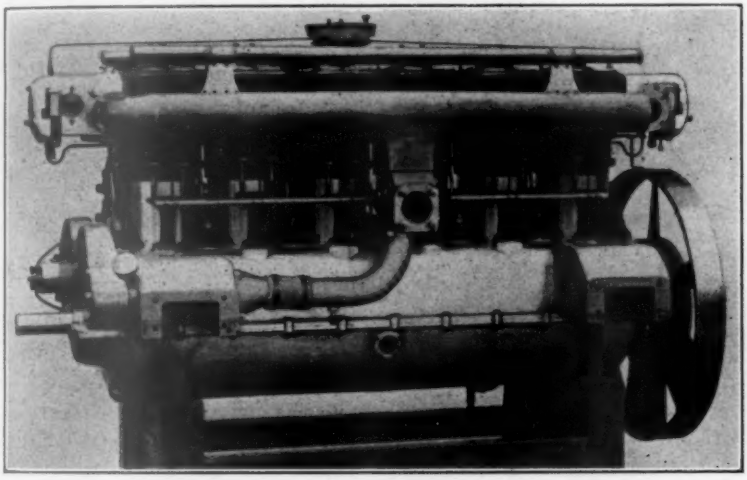




Plans and photographs of the passenger Zeppelin "Schwaben."

ders attached to the rear of the hull and operated from the forward gondola. The ship can operate with a slight negative buoyancy due to the dynamic lift of the air upon the under side of the envelope when driven at full power in an inclined position. To balance with engines stopped, ballast and gas valves must be handled as in other air-ships. As the ship ascends gas is automatically released from each gas bag. The pilot can open 8 gas valves at once if he wishes to descend. Stability of route is given by a proper arrangement of fins on the rear of the hull. Water ballast is carried in tanks near each of the three cars. It can be

FIG. 6.



Maybach motor.

discharged from the pilot station by manipulating the valves. Before a landing, the motors are stopped, and if, when way is lost, it is observed that the head is heavy, the pilot opens the valve of the forward tank and discharges water until the ship comes to an even keel.

Propellers.—The propellers are mounted on side brackets. The two forward propellers are two-bladed and run at one-half the speed of the two after propellers, which are four-bladed. By use of clutches any propeller can be reversed or stopped regardless of the others.

The following details of the naval Zeppelin L1, lost in a gale over the North Sea, September, 1913, were published after the accident and are considered trustworthy.

Volume	22,000	cubic metres.
Length	160	metres.
Diameter	15	metres.
Speed	85	kilometres per hour.
Gas bags	18	gold-beater's-skin.
Radius of action	55	hours (at reduced power).
Power, horsepower	500	in three Maybach units.
Weight	27,000	kilogrammes total.
Net lift	7,500	kilogrammes.
Fuel and oil	3,000	kilogrammes.
Crew	17	

The crew was made up as follows:

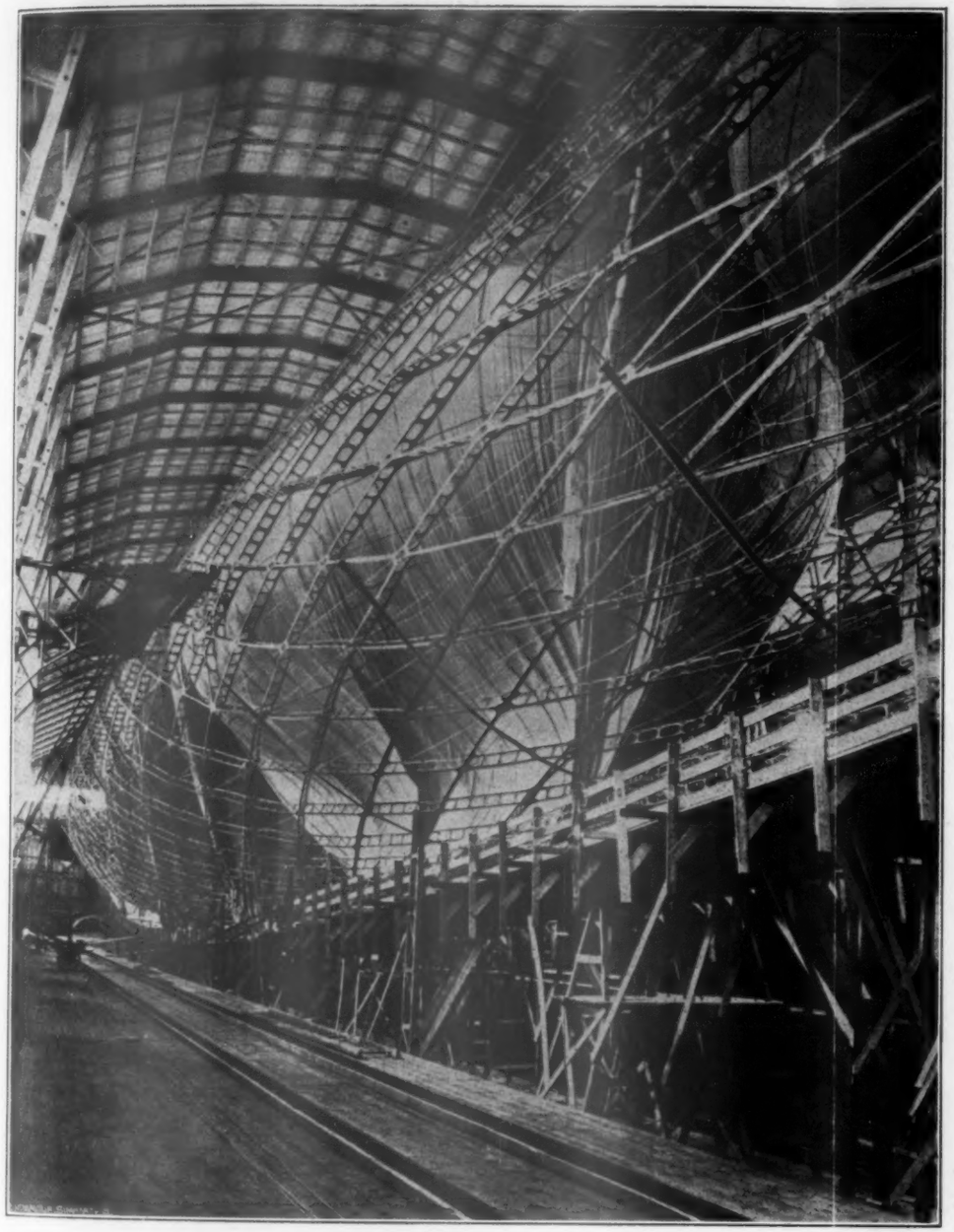
1 naval officer commanding.
1 engineer officer, chief engineer.
1 quartermaster, vertical rudder.
1 quartermaster, horizontal rudder and valves.
2 quartermasters, relief for above.
1 radio operator.
1 relief for above.
3 machinists.
3 relief machinists.
3 extra men, passengers and gunners.

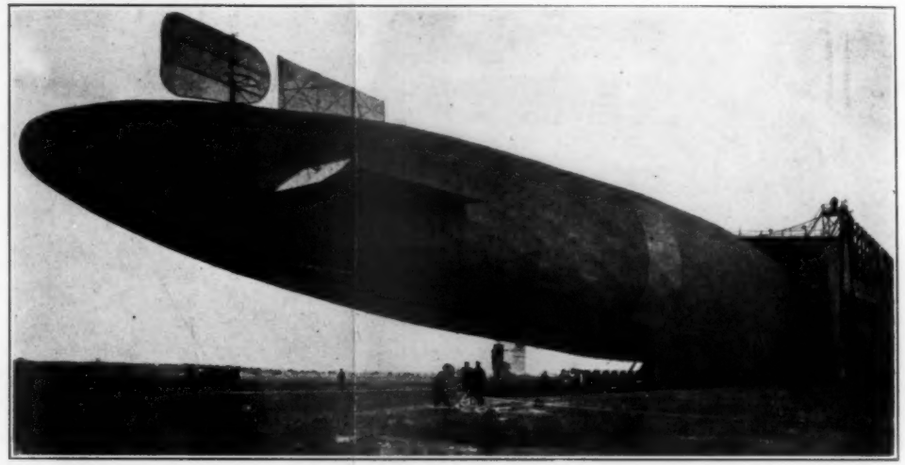
The second naval Zeppelin L 2 represented the latest development of the type, and before she met with an accident on her acceptance trial was reported to have attained a speed of 60 miles per hour with 900 horsepower. The volume was 27,000 cubic metres, and radius of action estimated at 70 hours at reduced power.

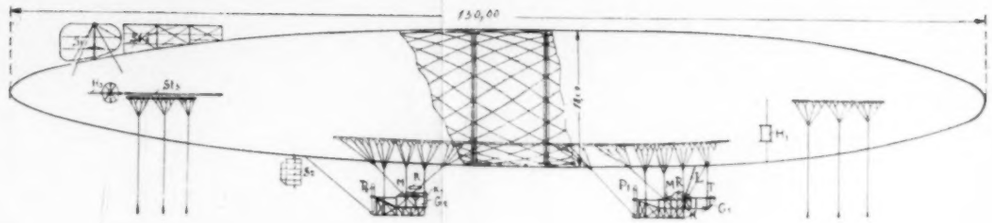
Schütte Lanz (Fig. 7).—The rigid Schütte Lanz air-ship differs from the Zeppelin in having its frame made of wood. It is hoped that this construction will be lighter and tougher than metal and that the ship will not be so easily injured by contact with the ground as are the Zeppelins. The details of construction are not made public.

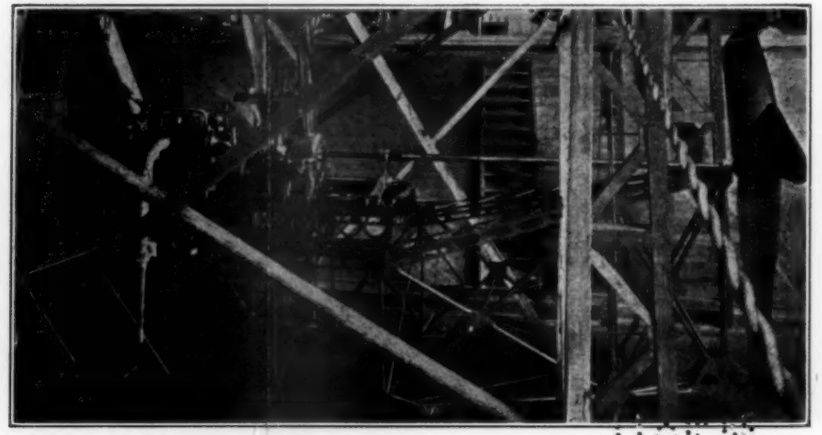
Parseval Dirigible (Figs. 8 and 9).—The non-rigid German air-ship is represented by the Parseval. In 1906 the Luft Fahrzeng Gesellschaft was formed to take over the patents of Major Professor Dr. A. von Parseval and to construct and

FIG. 7.









Schütte Lanz wood framed rigid dirigible.

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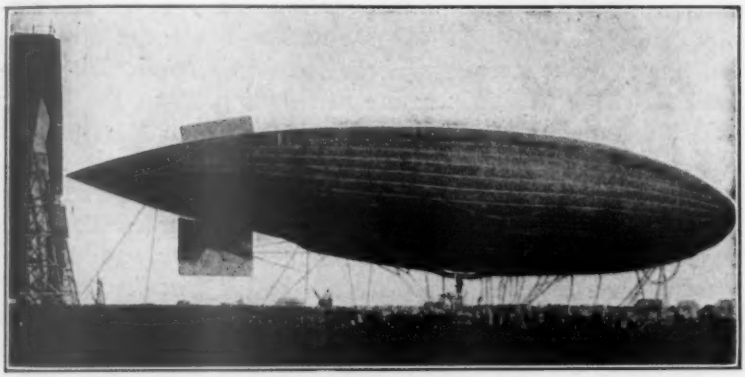
develop non-rigid air-ships. A research laboratory was endowed at the University of Göttingen and practical experiments under-

FIG. 8.



Parseval non-rigid dirigible.

FIG. 9.

Parseval dirigible of Fig. 8 boxed for shipment to Japan.

taken at the works in Bitterfeld. To date 20 ships have been built, and there have been no serious accidents. One ship was destroyed in its shed by fire due to carelessness.

The principal characteristic of the Parseval ship is that it has had its design based on engineering tests. The torpedo-shaped form of the envelope is the result of tests at Göttingen to obtain a shape giving the least head resistance for a given volume. The arrangement of fins and rudders for stability of route and control was also studied by the use of small models in the Göttingen wind tunnel. The strength of envelope fabric required is determined from the known pressure distribution about the hull in motion, as found by wind-tunnel tests at Göttingen, together with the known physical properties of the fabric as given by the testing machine.

The calculation of the bending moment in the envelope and the suspension of the car may be of interest. Only the general procedure can be given here. The method is described in detail by Haas and Dietzins in "Stoffdehnung und Formänderung der Hülle von Prall Luftschiffen," published by J. Springer, Berlin.

Strength Calculation for Dirigible (Non-rigid).

Buoyancy Curve.—Erect a curve representing the buoyant force of the envelope. Such a curve has ordinates proportional to the cross-sectional area at each point along the length of the envelope. This curve is shown in Fig. 10 as B.

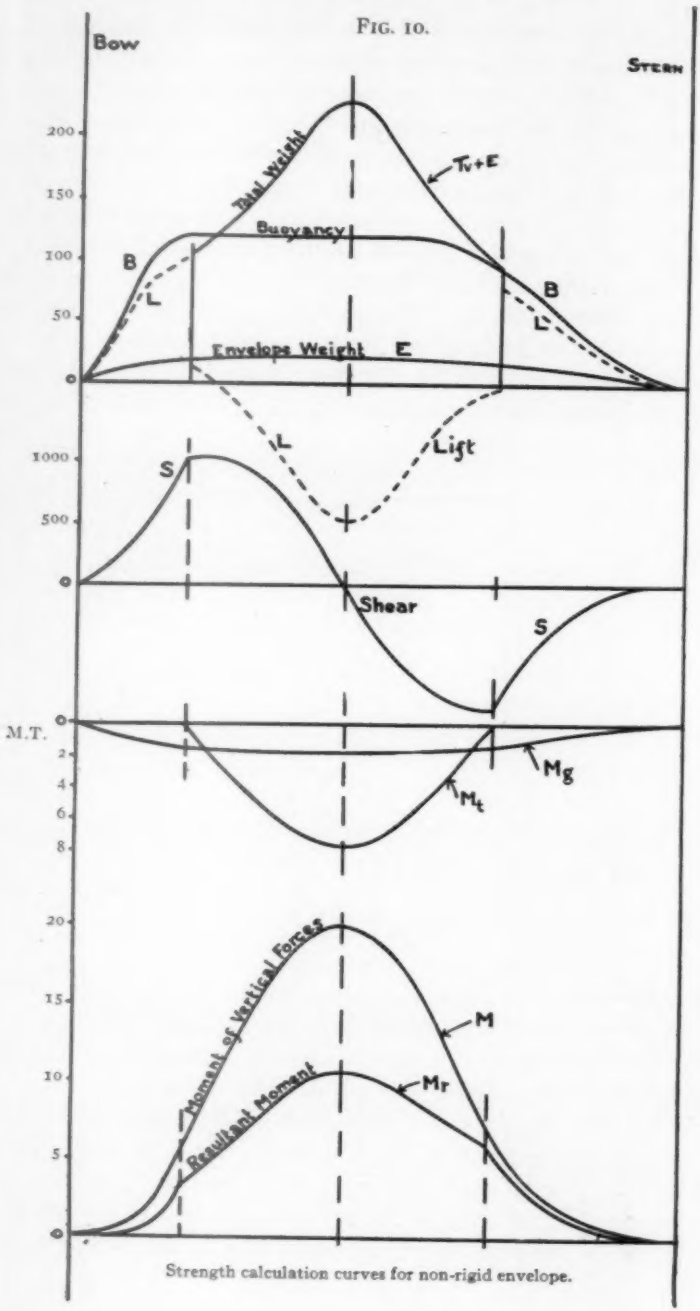
Envelope Weight.—Erect a curve E representing the weight of the envelope with all attachments, such as fins and rudders.

Car Weight Curve.—The car is suspended from the belly-band attached to the envelope by a system of rigging, and its weight is distributed among the individual ropes in a manner that can be estimated for any given inclination of the fore and aft axis of the ship. Suppose, in Fig. 11, the ropes each have a different tension T. There is then a horizontal component T_h and a vertical component T_v for each such rope of the suspension. Estimate the value of T_v for each rope and construct a curve superposed above the curve of envelope weight. The resultant represents total weight, $E + T_v$.

Load Curve.—The difference between the total weight curve and the total buoyancy curve is the load curve L, whose total area is zero, but which lies both above and below the axis.

Shear Curve.—The integral of the load curve L, by a well-known principle in applied mechanics, represents the shearing force at any section. Such a curve is drawn at S.

FIG. 10.

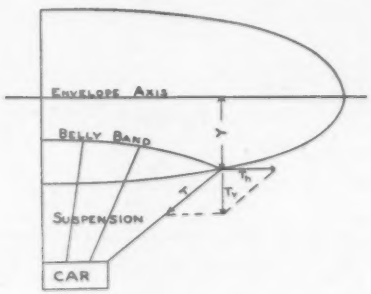


Strength calculation curves for non-rigid envelope.

Bending Moment Curve.—The integral of the shearing force curve is the curve of bending moments M. The nature of this bending moment is to cause the ends to be raised, and we represent it as a positive bending moment. This is the moment due to the vertical forces. In addition to this moment, we must superpose the moments due to horizontal forces.

Gas Pressure Moment Curve.—Over a cross-section of the envelope the pressure difference at the top is greater than that at the bottom, due to the difference in weight of a column of gas and an equivalent column of air of the same height. If the pressure difference at the level of the axis of the envelope is p_o, the pressure difference at a distance y above the axis is $kyp_o + p_o$, or an excess of kyp_o. The moment about the centre of such a force on

FIG. 11.



an element dA of the cross-section is $dM = kyp_o dA.y$, and integrated over the cross-section.

$$M_g = \int kp_o y^2 dA.$$

In the case of a circular cross-section, this integral reduces to the form $M_g = KR^4$, where R is the radius. We may now calculate the value of M_g, the moment due to gas pressure for each section of the envelope, and plot the curve M_g of Fig. 10.

Moment of Horizontal Components.—We have seen that the force T in each element of the suspension has a horizontal component T_h. The moment of this force about the centre of the envelope is yT_h, where y is the vertical distance of the point of attachment of the rope below the centre line of the envelope. By

calculating yT_h for each rope of the suspension, we can plot the curve M_t representing the bending moment due to the horizontal forces acting in the suspension.

The moments due to the above and to difference in gas pressure tend to lower the ends of the envelope, and, according to convention, are negative moments and should be laid off below the axis of the plot.

The difference between the ordinates of a curve representing $M_g + M_t$ and the curve of moments M gives a curve of resultant moments M_r. This curve represents the actual bending moment in the envelope at every point. It is important to adjust the design so that this curve shall be as nearly uniform as possible. A large hump in the middle of it represents a high bending moment at the midship section.

The midship section is stressed by the internal gas pressure p according to the well-known boiler formula:

$$f_c = \frac{\pi r^2 p}{2\pi r} = \frac{rp}{2}, \text{ where}$$

f_c = pounds tension per foot circumference.
r = radius in feet.
p = pressure above atmospheric in pounds per square foot.

The tension on the bottom of the envelope due to the bending moment M_r is represented by:

$$f_m = \frac{M_r R}{I}, \text{ where}$$

R = radius of section in feet.
$I = \pi R^3$ the moment of inertia of the circumference.
M_r = resultant moment at midship section in pounds-feet.
f_m = stress in envelope in pounds per foot run at top and bottom of section.

The total stress in the envelope at the bottom of the midship section is a tension.

$$t = f_g + f_m$$

At the top of the envelope at the midship section the force f_m is a compression. The resultant tension is here:

$$t = f_g - f_m$$

FIG.

Parseval

Type	(Projected) Military airship.	(Projected) Passenger airship.	Military airship.	Passenger airship.
Volume	22,000 cb.m.	22,000 cb.m.	16,000 cb.m.	16,000 cb.m.
Length	160 m.	160 m.	137 m.	137 m.
Height	24 m.	24 m.	24 m.	23.5 m.
Diameter of envelope, max.	16.5 m.	16.5 m.	15.5 m.	15.5 m.
Motors	4 of 180–200 H. P.	4 of 180–200 H. P.	4 of 180–200 H. P.	3 of 180–200 H. P.
Propellers	2 pair four-bladed	2 pair four-bladed	2 four-bladed	2 four-bladed
Bulkheads	2	2	1	1
Cars	2	2 and 1 cabin	1	1
Maximum speed in metres second:				
(*a*) with 4 motors	23	23	22–23	.....
(*b*) with 3 motors	20–21	20–21	20	21
(*c*) with 2 motors	17–18	17–18	17–18	18
(*d*) with 1 motor	.....	.....	.....	.....
Useful lift	8000 kg. for 15° C. and 760 mm. barometer	7700 kg. for 15° C. and 760 mm. barometer	6300 kg. for 15° C. and 760 mm. barometer	7200 kg. for 15° C. and 760 mm. barometer
Radius hours:				
(*a*) with 4 motors	26.5	20	20	.....
(*b*) with 3 motors	35	27	27	20
(*c*) with 2 motors	53	40	40	30
(*d*) with 1 motor	.....	.....	.....	.....
Radius kilometres (tank fuel only):				
(*a*) with 4 motors	2200 km.	1650 km.	1650 km.	.....
(*b*) with 3 motors	2600 km.	2000 km.	2000 km.	1500 km.
(*c*) with 2 motors	3300 km.	2500 km.	2500 km.	2000 km.
(*d*) with 1 motor	.....	.....	.....	.....
Maximum altitude	2500 m.	2500 m.	3000 m.	3000 m.
Distribution of useful lift:				
Crew	1200 kg. (15)	640 kg. (8)	720 kg. (9)	640 kg. (8)
Fuel	3600 kg.	3600 kg.	3600 kg.	2700 kg.
Radio and cabinet	250 kg.	250 kg.	250 kg.	250 kg.
Armament	500 kg.	.....	500 kg.	.....
Equipment, searchlight, etc.	140 kg.	200 kg.	140 kg.	140 kg.
Ballast and passengers	2310 kg.	3000 kg.	1100 kg.	3470 kg.

12.

Air-ships.

Military air-ship.	Military air-ship.	Military air-ship.	Military air-ship.	Military air-ship.	Altitude ship.
15,000 cb.m.	10,000 cb.m.	9,300 cb.m.	7,400 cb.m.	2,400 cb.m.	10,500 cb.m.
125 m.	ca. 95 m.	95 m.	86 m.	53 m.	90 m.
24 m.	23 m.	23 m.	22 m.	15 m.	26 m.
16 m.	15 m.	14.5 m.	13.5 m.	9.5 m.	16 m.
4 of 180–200 H. P.	2 of 180–200 H. P.	3 of 180–200 H. P.	2 of 180 H. P.	1 of 120 H. P.	2 of 90 H. P.
2 four-bladed	2 four-bladed	2 four-bladed	2 four-bladed	2 four-bladed	2 four-bladed
1	.....	.....	.....	.....	.....
1	1	1	1	1	1
23	.....	.....	.....	.....	.....
20–21	.....	22.5	.....	.....	.....
17–18	19	18.5	21	.....	15
.....	.....	.....	.....	17	.....
5700 kg. for 15° C. and 760 mm. barometer	3000 kg. for 15° C. and 760 mm. barometer	3200 kg. for 15° C. and 760 mm. barometer	2550 kg. for 15° C. and 760 mm. barometer	800 kg. for 15° C. and 760 mm. barometer	3000 kg. for 15° C. and 760 mm. barometer
20	.....	.....	.....	.....	.....
27	.....	10	.....	.....	.....
40	15	13.5	10	.....	20
.....	.....	.....	.....	8	.....
1650 km.	.....	.....	.....	.....	.....
2000 km.	.....	810 km.	.....	.....	.....
2500 km.	1000 km.	900 km.	756 km.	.....	1100 km.
.....	.....	.....	.....	490 km.	.....
2500 m.	2000 m.	2000 m.	2000 m.	1100 m.	3800 m.
560 kg. (7)	560 kg. (7)	480 kg. (6)	400 kg. (5)	300 kg. (4)	560 kg. (7)
3600 kg.	1350 kg.	1350 kg.	900 kg.	300 kg.	900 kg.
250 kg.	250 kg.	250 kg.	250 kg.	.....	250 kg.
50 kg.	150 kg.	200 kg.	200 kg.	.....	50 kg.
200 kg.	.....	.....	.....	.....	150 kg.
1040 kg.	690 kg.	920 kg.	840 kg.	200 kg.	1090 kg.

In a non-rigid envelope the fabric is obviously unable to take a compressive force unless the internal gas pressure be sufficient to create a tension f_g superior to f_m.

The strength of the envelope is calculated from the most stressed portion, where $t = f_g + f_m$. The calculation is repeated for various inclinations of the axis of the envelope.

The following is a general description of the Parseval features (see Fig. 12):

Envelope.—The envelope is made to the plans of the Parseval designers by the firm of A. Riedinger, Augsburg. This is one of the oldest balloon factories in the world, and has developed great skill in cutting and working rubberized fabrics. The material is purchased and tested at the Parseval works, whose specifications must be followed. Riedinger further tests it for gas tightness and stretching, in order to guarantee permanence of form. The fabric is cut in strips by the aid of paper patterns from which an empirical allowance for stretch has been deducted. The allowance for stretch is based on tests of samples and on experience with previous envelopes. Fabric of ultimate strength of one ton per linear metre is used for small envelopes, and fabric of strength two tons per metre for envelopes over 8000 cubic metres in volume. Over the propellers the fabric is doubled to protect the envelope from splinters in case of propeller rupture.

The nose is stiffened to stand the wind pressure at high speeds, and to permit mooring to a mast in the open.

Two ripping seams are provided. In case of a forced landing in a storm, the pilot can instantly deflate the envelope by pulling the rip cords. This feature is common to all non-rigid ships and is a great advantage of that type.

The internal gas pressure is from 20 to 30 millimetres of water.

The loss of gas through the fabric is about 1 per cent. of the total volume per 24 hours.

The envelope is fitted with a lower gas valve, spring loaded or opened at the will of the pilot. There is also an upper gas valve for use in case the lower one sticks. Normally only the lower valve is opened, as it releases the heavy and impure gas.

Ballonets.—Inside the envelope are two air-sacs or ballonets of total volume about one-third of the envelope. Air is admitted to one or the other ballonet by means of a three-way valve in the

trunk leading to the blower in the car. The size of the trunk and capacity of the blower are calculated to supply air to the ballonets at a sufficient rate to permit a given rate of descent without loss of form.

Suspension.—The car hangs from the envelope on six steel cables attached at the top to crow's feet of flax rope (electrical insulation of the envelope from the car) which toggle into a belly-band or fold of heavy canvas sewed to the bottom of the envelope. The load on the belly-band is then carried by belts of canvas passing over the top of the envelope. Each belt is enclosed in a pocket of fabric to prevent longitudinal motion, but is otherwise free to slip and adjust the load equally on the two sides of the car. Fore and aft motion of the car is prevented by fore and aft wire stays. Each of the two forward stays passes under rollers on the car and becomes an after stay. In the centre of the horizontal portion is fitted a rack held by a pinion. By turning this pinion the car can be hauled forward or aft through a distance of about 2 feet 6 inches. This displacement of the centre of gravity gives a powerful steering couple to be used when the ship has not speed enough to make the horizontal rudders effective. The longitudinal equilibrium may also be adjusted without discharging or shifting ballast.

Car.—The car is built of steel tubing in a substantial manner to withstand shock of landing. It can be taken apart for shipment. A sound-proof cabinet is fitted for the wireless telegraph operator. The framing of the car is completely enclosed by sheet metal or fabric. The pilot stands behind celluloid windows. In the ships under construction the car will be water-tight to serve as a float in landing on water.

Motors.—Two Maybach motors are mounted to operate in tandem on the same shaft. The car is made elastic to avoid use of springs, and to preserve shaft alignment several cardan joints are provided. An effective muffler and a jacking device for starting the motors are usually fitted.

Propellers.—Two steel plate propellers, four-bladed, with reversing pitch, or two walnut propellers, two-bladed, with reversing clutch, are mounted on side brackets and driven by gearing from one or both motors.

Wireless.—The radius of the Huth wireless set is about 300 kilometres. Total weight, 250 kilogrammes.

Searchlight.—A searchlight lighted by current from a dynamo driven by the motor shaft is good to distinguish large objects on a dark night from a height of 1000 feet.

Instruments.—Engine telegraph from pilot, barograph, barometer, manometer for each ballonet, two manometers for gas, one aneroid pressure gauge for gas, one water gauge for cooling water, one oil gauge, one fuel gauge, one fire extinguisher, one surgeon's box.

Certain ships have also been fitted with a machine gun in the bow, and a bomb projector below the floor of the car.

Crew.—One chief pilot to maintain level, one pilot to maintain course, three machinists, one wireless operator, relief crew as required.

English Dirigibles.

English experience with air-ships was at first disastrous. The great rigid dirigible " Mayfly," built by Vickers, had a framework of aluminum alloy bars as in the Zeppelins, but the longitudinal strength was not sufficient and the ship's back was broken in the first attempt to launch her in 1911. The French Lebaudy air-ship " Morning Post," a semi-rigid, was lost the same year when she became entangled among telegraph wires and trees along a road near Farnborough. The cause of the accident was a wind slightly too great for the ship to manœuvre against.

From 1909 to 1913 the Royal Air-craft Factory built five small non-rigid air-ships of an experimental nature, ranging in volume from 600 to 6000 cubic metres. The last completed, the " Eta," of 6000 cubic metres, has made some very good flights. Its design is based on experience with the previous British air-ships and upon the purchased French and German dirigibles. In 1913 one Astra-Torrés 6500-metre ship and one Parseval 8800-metre ship were purchased. It is reported that these orders have been followed by further orders to these foreign factories. The great shipbuilding and armament firm of Vickers, Ltd., has secured the rights to build the Parseval air-ship in England, and Armstrong, Whitworth & Co. have secured the rights for an Italian ship, the " Forlanini." It is understood that three Forlaniñi semi-rigid dirigibles are to be acquired by the Admiralty. The

sudden expansion in dirigibles is due to the vigorous policy of the Admiralty in its desire to create an aërial fleet.

The following features of the "Eta," built by the Royal Aircraft Factory, may be of interest:

Envelope.—The envelope is made of "Continental" double diagonal rubberized fabric, treated with chrome yellow on the outside to protect the rubber from sunlight. Seams are gummed with rubber cement and stitched on a two-needle sewing machine by women especially skilled in this work. The form of the envelope is the result of tests in the wind tunnel at the National Physical Laboratory.

Suspension of the car is the ordinary French type by means of steel cables and crow's feet of flax toggled to a canvas belly-band.

Car is of steel tubing covered with fabric. No springs are fitted under the motors. The car is readily taken down for transport over seas.

Power plant consists of two 150-horsepower Salmson (French) motors driving through clutches and bevel gearing two four-bladed wooden propellers. Provision is made for swivelling the propeller axes in a vertical plane as in the latest Astra ships.

Crew is composed of one officer in charge, observer; one quartermaster to maintain altitude; one quartermaster to maintain course; three machinists.

For a landing, the assistance of about 40 men is required in windy weather, and provision is made for mooring by the nose to a mast in the centre of an open space.

Instruments.—One revolution counter, one barograph, one aneroid gas pressure gauge, two gas pressure manometers, two ballonet pressure manometers, one liquid compass.

Ballast.—In canvas water bags in car.

It should be stated here that the procedure of mooring to a mast was originated in England at the Royal Air-craft Factory.

Italian Dirigibles.

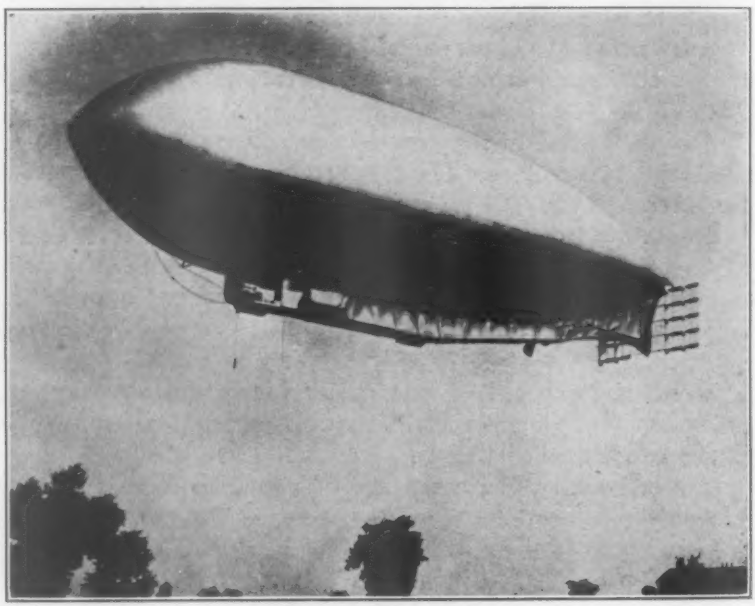
The Italian Government has three classes of dirigibles: the P class (small, of less than 5000 cubic metres), the M class (medium size, between 8000 and 12,000 cubic metres), and (under construction) the G class (20,000 cubic metres volume).

At the present time Italy has 5 P class and 5 M class, with 2 G class building.

The small P class ships have a speed of 50 kilometres per hour on a volume of 4500 metres, and are not considered suitable for war scouting. They are valuable for training purposes, however.

The M class is represented by five semi-rigid ships of 12,000 metres, designed by Captains Crocco and Ricaldoni. The keel is

FIG. 13.



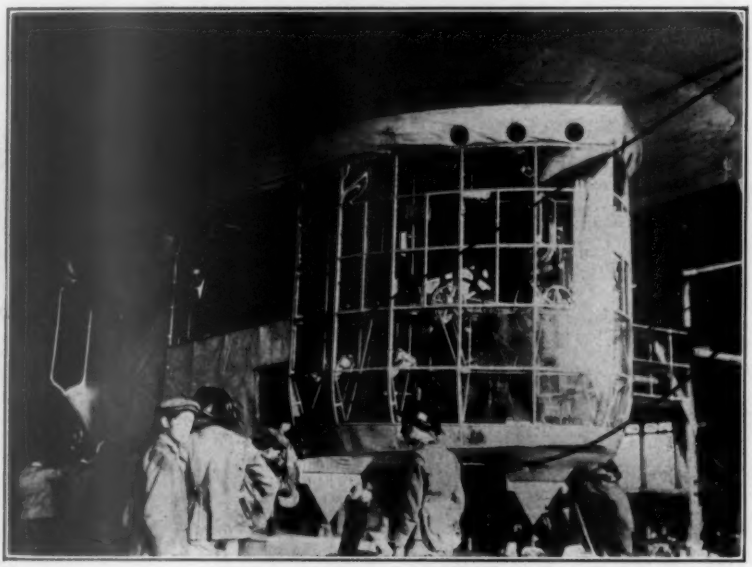
Forlanini semi-rigid "City of Milan."

a rigid structure built into the envelope. The car is a completely enclosed boat provided with windows. The crew are thus protected from the weather. A speed of 70 kilometres, or 44 miles per hour, is given by two 250-horsepower motors. Usually Italian motors are used: Fiat, Isotta, etc. Radius of action is 1000 kilometres, or a maximum flight of 35 hours at reduced power at an altitude of 1000 metres.

The "Forlanini" semi-rigid ships have recently been very successful. The Italian army has one ship of 12,000 metres,

and is reported to have under construction one G1 or "Forlanini" of 20,000 cubic metres, speed 72 kilometres, 800 horsepower. A larger ship is projected of volume 24,000 cubic metres and speed 100 kilometres on 1000 horsepower. The British Admiralty is reported to have recently ordered three "Forlanini" ships, one to be built in England and two to be built in Italy.

FIG. 14.



Car of Forlanini "City of Milan."

The "Forlanini" type is distinguished by a completely enclosed car which forms part of a long rigid keel extending the entire length of the envelope. The keel is crescent-shaped longitudinally and square-sectioned transversely. The ends of the keel are tied together by a steel cable running through the envelope.

The envelope is in two parts, meeting along the top centre line. The inner envelope is made up of 14 compartments. The inner and outer envelopes are kept apart by ballonets. The British ships are reported to displace about 12,000 cubic metres, length 72 metres, diameter 8 metres, two three-blade propellers

of diameter 4.2 metres, maximum speed 44 miles per hour, on two Fraschini motors of 100 horsepower each.

By virtue of the semi-rigid construction the ordinary suspension of the car from the envelope is avoided and the car placed inside the keel. Head resistance is, of course, reduced, and the power required for a given speed still more reduced.

The Italian army has at present one German Parseval non-rigid air-ship of 10,000 cubic metres and another ordered.

DISCUSSION OF TYPES OF DIRIGIBLES.

The three types of dirigibles—rigid, semi-rigid, and non-rigid—in all probability will continue to be built, as each possesses peculiar advantages.

The rigid Zeppelin type is considered to possess the following advantages over the other types:

(1) Possibility of constructing of enormous size with correspondingly great speed, radius of action, and weight-carrying ability.

(2) Cellular subdivision of gas bags, giving less danger from ripping or bursting of envelope. In a rigid ship one gas bag may be pierced by a shot without loss of more than one-twentieth of the lift.

(3) Preservation of longitudinal strength independent of gas pressure.

(4) Reduction of head resistance due to suppression of external suspension to car.

(5) Ability to descend rapidly, due to (3).

(6) Ability to go for long periods of time without material loss of gas, due to the fact that gas bags may be made of gold-beater's-skin.

(7) Long life, because outer covering of envelope is not rubberized or gas-tight.

(8) Form does not change, due to stretch of fabric.

(9) Less severe temperature expansion of gas in passing from sunlight to shade. The outer envelope and dead air space insulate the internal gas bags.

(10) Gas pressure is only slightly above atmospheric when at low altitudes, and the flow of gas from a shot-hole in a Zeppelin has about one-half the velocity of flow from a similar hole in a non-rigid envelope at the same altitude. Also in the former case

the flow of gas ceases when the gas below the level of the hole has escaped.

On the other hand, the large rigid air-ships are very costly, and require still more expensive sheds to house them. On the ground they are very unwieldy and require two or three hundred men to hold them against a moderate breeze. There is great danger of straining the rigid frame in a bad landing—an injury that destroys the usefulness of the ship. The rigid ship cannot be transported by rail or steamer.

The disadvantages of the rigid type are the corresponding advantages of the non-rigid type. For example, the peculiar advantages of the non-rigid may be enumerated as follows:

(1) They are less costly for the same service.

(2) Due to saving of weight of rigid frame, a non-rigid ship may be designed to have the same lifting power as the rigid ship, but with a 20 per cent. smaller envelope volume.

(3) The housing is less costly, due to smaller size. At the same time, several ships with envelope deflated may be stowed in a single shed.

(4) The non-rigid ship is not injured so easily on the ground. Its longitudinal strength is given by gas pressure, and is not affected by a bad landing.

(5) The smaller non-rigid ships can be moored to a mast in the open.

(6) The non-rigid can instantly deflate its envelope, if it has to land in a strong wind, by pulling the ripping panel.

(7) About 50 men can hold a 10,000 cubic metre non-rigid in a moderate breeze.

(8) The non-rigid ships can be easily deflated, taken apart, and shipped in several packages by motor truck, railroad, or steamer. This is a great advantage for naval purposes.

(9) Injuries to the envelope of the non-rigid ship are easy to repair, and, though the envelope may last but three years, it can be replaced at a cost of less than $2 per cubic metre.

Like all compromises, the semi-rigid dirigible, in an effort to combine some advantages, has combined some disadvantages of both the rigid and non-rigid systems. For example, the semi-rigid dirigible has advantages to some extent of the non-rigid type as enumerated above in paragraphs 1, 2, 3, 5, 6, 7, and 9, and advantages 1, 3, 4, 5, 8, enumerated for the rigid type. On

the other hand, the greatest advantage of the non-rigid type—its portability—it does not possess. The long keel is heavy, easily damaged, and cumbersome. It combines the vulnerability to puncture of the non-rigid ship with the unwieldiness of the rigid ship. Furthermore, the placing of the gasoline motors in a car built in the keel immediately below the envelope is a fire risk not to be ignored.[1]

It is probable that difficulties of construction render the rigid type desirable for ships of more than 16,000 cubic metres volume. Below this size, the non-rigid type appears to have the advantage. The semi-rigid system has been most satisfactory when applied to ships of volume near 16,000 cubic metres.

Air-ships of any type are in the position of small boats on the sea. It is impossible to navigate in a storm. It is true that a powerful high-speed Zeppelin could make headway against a wind that a less powerful non-rigid ship could not cope with. This advantage is not, however, a practical one, for the apparent advantage of the great rigid ship exists only while in the air. The larger ships can neither leave their sheds nor enter them when a wind is blowing that does not present insuperable difficulties for the non-rigid ships. A wind of 15 miles per hour is about the upper limit for the safe handling of a Zeppelin on the ground, where this wind must be taken broadside on (across the mouth of the shed).

A form of rotating shed mounted on a turntable has been built in Germany and should be an advantage in case of unfavorable wind. The construction is very costly, however.

ACCIDENTS TO DIRIGIBLES.

Disputed points in general design and possible improvements to be desired are best considered in the light of the accidents that have occurred. Unfortunately, the development of a new kind of transportation is inevitably accompanied by many accidents, and very often our attention is drawn more forcibly to the accidents than to the successful trips. This statement applies to dirigibles, submarines, subways, great passenger steamers, and 18-

[1] The Italian semi-rigid Forlanini dirigible "Citta di Milano" was destroyed, April 9, 1914, on the ground, by explosion of hydrogen and subsequent fire. Fifty persons were injured. Cause unknown.

hour trains. Accidents are horrible enough in themselves, and are, furthermore, unnecessary and useless if some lesson is not taught.

Considering first the non-rigid air-ship, we find that in the first Santos-Dumont ship the envelope collapsed in descending, due to the fact that blower and ballonet were not powerful enough to keep the gas pressure constant. The second Santos-Dumont non-rigid had its envelope collapse when it ascended in a rain storm, due to contraction of gas with cold. Here again the ballonet was not powerful enough. The conclusion from these accidents is that a powerful blower and large ballonet are absolutely essential to the safe operation of a non-rigid dirigible. However, in the cases cited the aëronaut was merely forced to descend abruptly. He was in no way injured.

In the Santos-Dumont 6 of 1902 the gas all ran to one end of the envelope, and lifted it up so that the controls could not bring the ship down to an even keel. There was danger of the suspension fouling the propeller and the bag bursting. This is a disadvantage of a large non-rigid ship. In the Santos-Dumont 7 silk non-gastight partitions proved a remedy. In the large non-rigid dirigibles projected for 1914, both in France and Germany, it is proposed to fit partitions in the envelope. There is danger of bursting in case a wave motion is set up, due to the impact of gas on the ends.

The Santos-Dumont 7 of 1902 was directionally unstable, due to its form of envelope. The same trouble has been had with other ships. The remedy lies in placing the centre of side resistance abaft the centre of gravity, as in the ordinary weather-cock or feathered arrow.

The "Republique," 1909, was destroyed when a propeller burst and cut the envelope. The cut quickly extended to a great tear, and the ship crashed to the ground. Ships since that day have employed a fabric that will not tear easily if punctured. Usually the fabric is made up of two or three layers of cloth, with intervening layers of rubber, the whole pressed together and vulcanized. The warp and weft of fabric in each layer are diagonal to the threads of the other layers. This is called diagonal doubling. Such fabric does not tear readily. An extra patch is placed on the envelope over the propellers to protect it from splinters.

A great many ships of all types have been lost by attempting to navigate in too high a wind. Examples are:

1901—Santos-Dumont 5, landed in a tree.

1902—Lebaudy, landed in a forest.

1907—Lebaudy, broke away from 200 men holding it and floated out to sea.

1909—Clement Bayard, broke away from 40 men holding it and blew into the Seine.

1911—"Morning Post," lost control and became entangled among telegraph wires and poles.

1913—Zeppelin L2, caught in cloudburst over North Sea and pounded into water, where the high sea broke her back.

The obvious conclusion from such experience is that an air-ship should have a speed sufficient to cope with the winds to be expected in her district. It is estimated that near Paris a ship capable of a speed of 45 miles per hour can manœuvre 234 days in the year, allowing for 75 days of fog, snow, or rain.

The speed of 45 miles per hour is figured as 8 miles per hour greater than the wind. It is usually considered that for safe handling a dirigible's speed should be at least 8 miles per hour greater than that of the wind. A speed of 45 miles per hour in France is the minimum for general military utility. It is possible that in the southern part of the United States, and near Cuba and Panama, a ship of 45 miles per hour maximum speed could navigate over 300 days in the year. In any case, the speed of our ships must be based on probable meteorological conditions. There is no ship yet designed to navigate in a tempest. A speed between 50 and 60 miles per hour is, however, practicable.

At the present time, hydrogen lifting two and a half pounds per cubic metre is the only gas used for air-ships. Coal gas gives only about half this lift. Also, gasoline or similar volatile distillates is the only fuel used for internal combustion motors. Unfortunately, both gasoline and hydrogen form explosive mixtures with air, and the motor has an ignition system and a hot exhaust pipe and muffler. The combination is a bad fire risk, and many ships have been lost by fire. In the past year or two the installation of wireless telegraphy and its high potential sending current is another source of danger. The car is in the non-rigid ships electrically insulated from the envelope.

The following ships lost by fire give an indication of the importance of the fire risk in design:

1879—Wölfert's rigid ship, a gasoline fire in the car ignited the hydrogen in the envelope.

1908—Zeppelin 3: torn by wind from moorings and blown aloft, where it caught fire and exploded.

1912—Zeppelin 10: burned in its shed at Düsseldorf.

1911—Parseval 5: burned in its shed at Münden.

1913—Zeppelin L 2: fire in the forward car ignited hydrogen in the envelope, where it exploded with great violence. It is reported that in this new ship an effort at high speed was to be made by reducing head resistance in every way. The cars were placed close under the envelope, and a connecting passage from forward to after car built inside the envelope. Leakage of gas into this passage (*Laufgang*), which was not ventilated, probably found its way to the forward car. A wind shield here made an eddy or suction behind it in the car, and air and gas from the *Laufgang* could easily have been sucked in. A flooded carburetor, red-hot exhaust pipes, or other cause could then have ignited the gas. In any case, the ship was completely destroyed in the air by the force of the explosion.

It seems that the cars containing the gasoline, motors, guns, wireless sending station, and other sources of fire should be kept well away from the envelope. In the rigid and semi-rigid ships the cars are very close to the envelope. In the non-rigid ships difficulties of suspension require the car to be hung on cables some distance below the envelope. So far as fire is concerned, the non-rigid ships seem safer, though the low car causes an increase of head resistance. The relief valves on the envelope are often placed at the bottom so as to discharge the heavier and more impure gas. In the non-rigid ships this may not be a source of danger, as hydrogen rises as soon as released and should not reach the car. The placing of gas valves should, however, be very carefully considered with reference to the suspension of the car.

It has been suggested that certain explosions of balloons in which no fire was carried may be due to discharge of atmospheric electricity. Thus a balloon on touching the ground may be charged with static electricity of potential equal to that of the upper air. Unless this potential be lost in descending, it may easily be possible for an electrical discharge to take place between

a part of the balloon touching the ground and some metal part, such as a gas valve. Gas valves are largely made of fibre, in view of this danger, and in dirigibles all metal parts are electrically connected. The envelope of most non-rigid ships has no metal parts, and is insulated from the car by crow's feet of flax rope.

The great difficulty in design of the rigid type ships is to get sufficient stiffness with small weight.

The following accidents represent the loss of several fortunes:

1897—Schwartz rigid: back broke from jar in striking ground.

1900—Zeppelin I: frame bent on first trip.

1900—Zeppelin II: frame broken by pounding on ground when anchored in the open.

1900—Zeppelin III: frame broken when jammed in door of shed.

1901—Zeppelin VIII: frame broken when jammed in door of shed.

1911—Mayfly, Vickers: back broken when launched.

The rigid hull of such ships is a most delicate structure and renders the rigid air-ship most vulnerable when improperly handled. The importance of a highly-trained personnel is apparent.

Due to the fact that the rigid hull cannot be deflated, the rigid type ships are only useful where adequate housing facilities are provided. The reliability of the motor is a vital factor in all dirigible operation. The Zeppelin II in 1900 was forced to land in an open field by motor stoppage. The ship was anchored to stakes driven in the ground, but a wind came up and pounded the vessel against the ground until the frame was broken. A non-rigid ship would have deflated the envelope in such a case. In 1901 motor trouble forced the non-rigid Santos-Dumont 5 to land on a roof. No damage was done, however. In modern dirigibles considerable weight is sacrificed to reliability in the design of the power plant. The motors are water-cooled, of moderate piston speed, and of substantial construction. Duplicate ignition systems are provided, and forced lubrication. It is becoming the practice to enclose the motors completely in order to protect them from rain and snow. Self-starting devices are frequently fitted, but in any case hand cranking or jacking arrangements are installed. Gauges are fitted to give warning of a low supply of fuel, oil, or water.

For any air-ship there is a limit to the wind which she can be expected to cope with, and it is obviously of great interest to have a trustworthy weather forecast before undertaking a voyage of any duration. In Europe the greater part of the violent storms come from the Atlantic, and their approach cannot always be known. The loss of the naval Zeppelin L1 over the North Sea in 1913 was primarily due to a violent and sudden rain squall of whose coming the weather forecasts gave no warning. In 1910 the Zeppelin "Deutschland" was caught in a strong rising current of air and the pilot was unable to prevent her being carried to a great height. The gas was chilled and contracted at the high altitude, and probably the pilot had opened his valves to check the ascent. In any case, the ship suddenly lost her buoyancy and dropped into a forest.

It is thus clear that it is not alone necessary that for safe dirigible operation the surface winds be not violent. The pilot should have assurance that disturbances in general meteorological conditions are not approaching. It has been found that pilot or sounding balloons, sent up before a voyage in a dirigible is started, may give valuable warning of unsettled conditions in the upper atmosphere. The pilot should have reports from observation stations in the vicinity, as well as a weather map showing the general barometric pressure distribution. During a voyage the barometer must be watched and its indications given careful consideration. In ships fitted with wireless hourly reports may be received from the home station. Safety in dirigible operation, questions of design not considered, must always depend upon the judgment of a weather-wise pilot and upon the trustworthy meteorological data that are supplied him.

The above discussion of accidents has been undertaken here in order to emphasize the vital importance of:

(1) Sufficient blower power and ballonet volume for non-rigid ships.

(2) Partitions in long non-rigid envelopes to prevent shifting of gas.

(3) Sufficient fin area abaft the centre of gravity to give directional stability.

(4) Provision against envelope of a non-rigid ship ripping when punctured.

(5) Sufficient speed to cope with winds to be expected in the district.

(6) Every possible precaution against fire.
(7) Electrical connection of metal parts.
(8) Adequate housing for rigid ships.
(9) Reliable motors.
(10) Correct weather forecasts.
(11) Experienced personnel.

In nearly all the accidents cited there is some one cause that might be prevented in subsequent ships. In this way improvements in design and operation have been brought about that now make a dirigible a fairly safe and useful method of transportation. The press naturally describes an accident in great detail, but, now that successful aërial voyages are of such frequent occurrence, mention of such performances is only made when the breaking of a record or the presence of distinguished persons gives news value to the report. For example, the three Zeppelins —"Hansa," "Sachsen," and "Viktoria Luise"—during the past summer made passenger trips every fair day of from two to six hours' duration without a single accident. Long-distance trips were also made between various German cities, and one to Copenhagen.

COMMERCIAL USE OF DIRIGIBLES.

Due to high cost of maintenance, some danger, and dependence upon weather conditions, air-ships have not yet been proved of great commercial value. It is true that thousands of passengers have been carried by the Zeppelins of the Delag Company in Germany, but this company has been heavily subsidized in order that its operation should not show a loss. The entertainment of tourists is a legitimate commercial enterprise, but the air-ship cannot be considered of real service to commerce and industry until it can maintain regular schedules between fixed points that men's affairs require them to visit. The passenger-carrying business so far has been of the nature of sight-seeing trips up the Rhine or around and over Berlin. There is no more delightful way to see the country. Provided with a good map, a passenger can become acquainted with a great area of country in a few hours' time. This facility for observation leads at once to the consideration of the use of air-ships in time of war.

MILITARY USE OF DIRIGIBLES (Figs. 15, 16, 17, 18).

The dirigible operating in clear weather at an altitude of some 5000 feet is fairly safe from gun-fire and yet not too high for a trained observer to detect the movements of large forces on the ground, general features of fortifications, number and type of ships in a harbor, presence or absence of bridges and railroad tracks. The dirigible can stop its motors and float slowly above

FIG. 15.

Neuhausen from a height of 3000 feet.

ground it is desired to observe. The aëroplane cannot perform such service except by circling above a given area, thus reducing its fuel supply and future usefulness. The great test in military operations of the dirigible will be for long-distance reconnoissance. In a country whose probable enemies lie within the radius of action of air-craft, dirigibles may be used at or before the opening of hostilities to pass over the enemy's frontier to observe the mobilization of troops, their direction of march and probable destination. A dirigible, unlike an aëroplane, is fitted with wireless telegraph both for sending and receiving messages, and

may keep in constant communication with its base. The radius of action in a calm of large rigid air-ships may be 2000 miles, and medium-sized non-rigid ships 1000 miles. An aëroplane cannot be depended on for more than 400 miles when an observer must be carried in addition to the passenger. A dirigible can save fuel by drifting with the wind, and it is well known that by selecting a suitable elevation a favorable wind can very often be found when the wind on the ground is contrary.

FIG. 16.

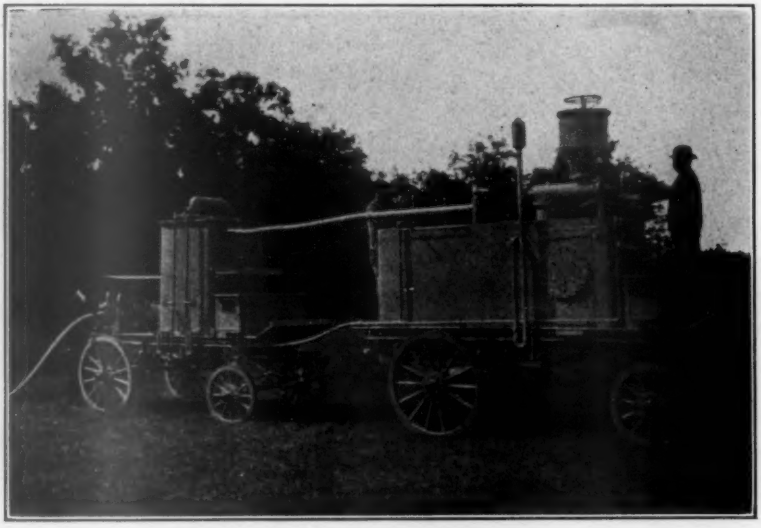
Neuhausen from a height of 3000 feet. Telephoto from dirigible.

The greatest usefulness of the dirigible will be at night. At the present time aëroplanes cannot be flown at night. The dirigible at night can travel close to the ground without danger from gun-fire, and can observe the extent and disposition of camps.

For pure reconnoissance work an army could use large rigid dirigibles for distant scouting to develop the enemy's principal movements preceding the actual meeting. Due to its portability, any expeditions into the interior of an enemy's country or in the colonies would be best served by non-rigid dirigibles. These ships are easily crated for shipment, and can be inflated in the field from bottled hydrogen or a portable gas plant drawn by

a motor truck. Large sheds are not necessary, as the ship can be moored in the open to a post in good weather and deflated in a violent storm. In cases where both rigid and non-rigid air-ships might be used, the non-rigid ships might observe from a safe altitude the progress of a battle and the effect of artillery fire. Aëroplanes would be used for transportation of staff officers, dispatch duty, and scouting within the limits of the battle-field. The same functions at night would be performed by the non-rigid dirigible.

FIG. 17.



Portable hydrogen generator.

In case of siege, where the enemy has possession of a great expanse of surrounding country, communication with the besieged forces could be had by means of a dirigible of sufficient radius of action. Its going and coming would be masked by darkness.

The use of dirigibles in modern wars will be greatly restricted by the enemy's aëroplanes, which must be supposed superior both in speed and climbing power. On the other hand, a dirigible will mount several machine guns and, having a steady gun platform, can deliver a much better directed fire than the aëroplane. It is

not clear what might be the result of an aërial skirmish between a scouting dirigible and the enemy's aëroplanes. However, a unit of a dirigible fleet is so much more valuable than a whole squadron of aëroplanes that it seems unlikely that a dirigible would seek an encounter. In the case of modern armies, where aëroplanes may be supposed numerous and their pilots ready to take risks, the operations of dirigibles will be, no doubt, chiefly conducted under cover of darkness or in strategic reconnoissance far removed from the field of battle.

FIG. 18.

Gun for firing at air-craft.

A large dirigible can carry over half a ton of bombs or torpedoes. In view of the great target which it presents, and the provisions made in European armies for the attack of dirigibles by shrapnel fire, it is unlikely that it will be attempted to drop bombs on an army in march or upon a fortified place. Furthermore, at night it may not be possible to drop bombs with any chance of hitting a given object. There will be cases, however, where a dirigible may be sent out to destroy a bridge, an enemy's dirigible shed, an arsenal, a canal lock, or other large object. The dirigible can make its journey by night, and before dawn, as soon as there is sufficient light, can descend close to its target.

drop half a dozen 100-pound gun-cotton torpedoes, and be away before she has been fired on. The surprise is no doubt to play an important part in any offensive operations of dirigibles.

The effect of bombs dropped from aloft in no way compares with that of shells from great guns on account of lack of penetration before explosion. The best that can be expected is a surface explosion and incendiary effect. The moral effect of dropping bombs into an enemy's camp at night must not be ignored. Doubtless, the damage may not be very great, but the effect of hourly explosions would certainly be depressing. A camp offers a large target, and a dirigible might easily hover above it all night above the range of searchlights. Its motors would be stopped or used at low power to hold position. Mufflers can be made as effective as in automobiles.

The rules of civilized warfare probably will not tolerate the dropping of bombs upon an enemy's city, and in case the place is besieged and non-combatants warned to leave it, bombardment by artillery will probably be more effective than dropping bombs from an air-ship during the night.

It seems to be the general opinion that the use of dirigibles will be more for reconnoissance than for offensive operations, but that in special cases offensive operations promise a chance of success.

NAVAL USE OF DIRIGIBLES.

The large rigid type dirigible may be of service to a navy whose probable adversaries have dock-yards and naval bases within the radius of action of such air-ships. The opening of hostilities might be preceded by a dirigible reconnoissance over the enemy's sea-coast to observe the disposition of his fleet. A dirigible might easily pass over all of the enemy's great dock-yards and naval bases and so ascertain whether the enemy's fleet be concentrated or scattered, the number of ships engaged in coaling, the number of ships in dry dock or otherwise out of action. It might well be that such reconnoissance would reveal such a condition of unpreparedness that, without formal declaration, war might be opened by an inferior force with a fair chance of destroying a division of the enemy's fleet before the other units could be mobilized.

For such strategic reconnoissance the great endurance and radius of action required indicate the rigid type ship as more suitable than the medium-sized non-rigid ship.

After war has been declared, if it be determined that the enemy is to take the offensive with one out of several probable objectives, it will be of vital importance for the defending navy (which we might assume inferior in force) to keep its fleet concentrated and endeavor to engage a portion of the enemy's superior fleet under advantageous conditions. The enemy's tactics might be to send a few ships to make a demonstration at several points and then to throw his main force upon another point which he might expect to find undefended by ships of the defending fleet. If all probable points of attack were patrolled by non-rigid dirigibles, it might be possible to determine the enemy's plan of attack and the number and power of the units in each of his subdivisions. The defending fleet could then select its conditions of battle and engage with a part of the enemy with a definite knowledge of his power and of the location of the other division of his fleet.

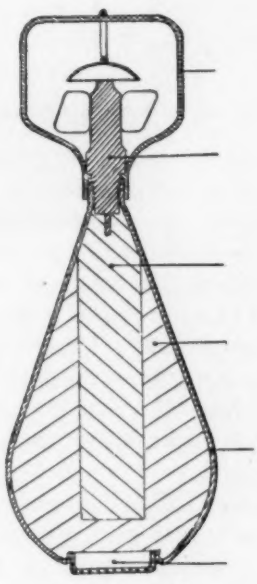
The number of dirigibles needed for a complete patrol of extensive coastal waters and islands would indicate the use of non-rigid ships whose radius of action is sufficient. This service could also be undertaken by hydro-aëroplanes, but, since the scout is waiting for the enemy to come within, say, 200 miles of a given point, the hydro-aëroplane could hardly afford to proceed to a point 150 miles out to sea, there to circle round until the enemy is sighted. The dirigible can float about with motors almost stopped for a day or more without great loss of fuel.

On the other hand, the enemy with the superior fleet might wish to know the location of the defending fleet in order to seek it out and destroy it or to blockade it in port. If the action were to take place at a great distance from the enemy's base, an advanced base near the field of operations would be seized, portable non-rigid air-ships set up and inflated, and sent out on definite scouting expeditions.

In general it may be considered that the offensive power of air-ships would have little effect upon armored decked battleships. Bombs and torpedoes (Fig. 19) will burst on the surface of such decks, turret roofs, etc., and do local damage, but probably

will not injure any vital parts. A ship is a small target to hit from the altitude of 5000 feet, which is required by day to be safe from gun-fire. At night an air-ship may pass low over a ship, but in war time no man-of-war will show lights, and, unless the moon be bright, the dirigible has small chance of finding the ship. It is stated by some pilots that when an air-ship is over a steam vessel a red glow is seen down the funnels. A bomb dropped down a funnel would certainly seriously damage the

FIG. 19.



Dirigible torpedo.

uptakes. It may well be considered prudent to fit gratings over the top of smoke-pipes on battleships.

As in the case of military operations, there may be special cases when a dirigible may be required to drop incendiary or high-explosive bombs on dock-yards, drydock caissons, vessels building, magazines, and workshops. Great damage might be done, but the battle fleet could not in this way be greatly reduced in power.

It seems that the principal function of the dirigible in naval

warfare is to supplement the work of scout cruisers, and that its offensive powers would rarely be called upon.

In attempting to pass through waters in which mines have been laid, a dirigible could possibly conduct counter mining operations. A dirigible can also give warning of the presence of submarines, and, if required, could rid a passage of these dangerous craft by launching bombs upon or near them. For this duty the dirigible may pass at a very low altitude, as she has little to fear from a submarine boat, unless the latter be running on the surface.

Dirigibles will not revolutionize naval warfare, but may play an important, if auxiliary, part in it.

FUTURE PROGRESS IN DIRIGIBLES.

Progress in dirigible design will probably continue to be directed along the lines of rigid, non-rigid, and semi-rigid types, each type being specialized for different functions.

It does not appear likely that any gas other than hydrogen will be used, but it is not clear that gasoline is the fuel best suited to dirigible motors. The adoption of a less dangerous fuel than gasoline will be a step in advance. Tanks may be kept under pressure of carbonic acid gas or other non-inflammable gas.

Improvement in radius of action may be expected from improvements in motors, both in power for a given weight and in economy of operation.

The rubberized fabric of dirigibles at best allows a leakage of gas of about ½ per cent. to 1 per cent. per day. In a 500,000 cubic foot ship this is a serious matter, and in 10 days a loss of lift of 10 per cent. may result. Laboratory experiments show various oiled and varnished silks to be more gastight than rubberized fabrics, but such silks have not yet been made sufficiently strong and durable for practical use. Gold-beater's-skin is gastight, but very expensive and difficult to handle. It may be expected that the future will bring forth an improved fabric.

Since the safety of a dirigible and its general usefulness depend to a large extent on speed, it is certain that every effort will be made to increase speed. The present speed of 50 miles per hour, when increased to 60 miles per hour, will give us a vastly more serviceable air-ship.

At the present time a dirigible in thick fog, rain or snow is likely to become lost and unable to return to its station. The German Zeppelin which landed at Luneville, France, recently in a fog is a case in point. It was most embarrassing to the Germans to have the French authorities become familiar with details of this ship. Since then experiments have been made in Germany to guide dirigibles enveloped in fog by means of wireless signals sent from two points. The relative intensity of signals received from the two stations by the dirigible is proportional to the relative distances of the ship from those stations. The method is reported to have been of some assistance. We may look in future to a perfection of such methods of orientation.

The future will also doubtless bring a multiplication of air-ship stations, each lighted at night by distinguishing lights.

Automatic devices for regulating the ballonet pressure are under consideration and will probably prove of some help to the pilot.

In short, we may expect progress to be made in speed, power, radius of action, safety, and reliability. It does not seem likely that it will be necessary to go to enormous sizes to accomplish this advance. Size in itself is a grave disadvantage.

Meteorology, though not a part of air-ship design, will lend valuable assistance in operation by a better knowledge of the atmosphere. A great deal of attention is being paid to the upper air currents, and it may reasonably be expected that the future meteorological forecasts will predict the conditions in the upper atmosphere with the precision of its present bulletins on conditions near the surface of the ground.

Improvement in the past five years has been very rapid, but there is yet hope that further improvement may be made and that in the near future the dirigible air-ship will be not only an engine of war but a valuable agent in the service of commerce and industry.

Much of the expected improvement in the general utility of air-ships may be expected to result from research in the aëronautical laboratories maintained by the governments of Germany, France, England, and Italy. The practical application of these results of laboratory research will be made by the young men who are being trained as aëronautical engineers in the engineering schools.

Large Cylinders for Locomotives. ANON. (*Sci. Amer.*, cx, No. 8, 155.)—The Test Department of the Pennsylvania Railroad has been experimenting with superheater locomotives. As a result it has been determined that when a locomotive is converted from saturated to superheated steam, its cylinders should be enlarged. It is found that to secure maximum economy, the cylinders should be enlarged to such an extent that the maximum indicated horsepower will be developed at a cut-off not exceeding 30 per cent.

Electric Lights at Low Cost. ANON. (*Sci. Amer.*, cx, No. 8, 155.)—While it is obvious that an electric lighting system is a most desirable feature in an automobile, the high prices at which most of such systems are offered to the public preclude their use by many owners. Realizing this, a well-known manufacturer of automobile specialties has just brought out a new electric lighting system of novel construction; the principal feature of which is that it can be easily installed and sells for only $12. The system comprises a dash lamp, a tail light and a portable trouble lamp. The body of each lamp is made of hard rubber instead of metal and contains a powerful lens. The tail lamp has a red lens for the warning signal and a slot underneath, with a white light for illuminating the license plate.

Evaporative Efficiency of Oil. ANON. (*Amer. Mach.*, xl, No. 14, 592.)—The evaporative efficiency of oil, when thoroughly atomized in a well-designed burner, is considerably higher than that of coal. Results of trials show that 1 lb. of crude petroleum with a net calorific value of from 18,000 to 18,250 B. T. U., will evaporate from 14½ to 15 lbs. of water, from and at 212° F. This is approximately 50 per cent. more than the same weight of coal would evaporate.

Rescuing from Submarine Boats in European Navies. ANON. (*Sci. Amer.*, cx, No. 12, 245.)—The subject of saving the lives of the men on submarine boats, the mechanism of which has become deranged, has been attracting considerable interest throughout the world recently. The importance of this subject was shown by a recent disaster in the British Navy. Several European navies have installed apparatus on their submarine boats for renewing oxygen and absorbing the products of respiration of the men on the boat for a period of 72 hours, during which time it is usually possible to effect a rescue, which otherwise would be valueless, as the men would have suffocated. Another popular method is to place in the boat a number of little machines designed to shut off the respiratory organs of the wearer from the water, and permit him to breathe fresh air supplied by a special device, until he can rise to the surface of the water, after which the device may be discarded; the balance of the apparatus serving as an ordinary life preserver until rescue can be effected.

THE RADIATION OF THE SUN.*

BY

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IT is really extraordinary how much has been found out about the sun, when it is considered that the sun lies at the immense distance of 93,000,000 miles. There are various methods of ascertaining the distance of the sun, resting upon extremely diverse foundations, so that the close accord of their results to within about one-tenth of one per cent. gives us great confidence in the accuracy of the mean value. The angular diameter of the sun is also known to a great accuracy, and from this and the distance one determines at once that the diameter of the sun is 865,000 miles. How great this is as compared with the diameter of the earth—7,918 miles! From a consideration of the motions of the earth and the moon, it is found that the mass of the sun is 332,800 times the mass of the earth. In accordance with this, the gravitation on the sun is enormous compared with that upon the earth, so that a body which weighs 100 pounds at the earth's surface would be pulled toward the centre of the sun from the sun's surface with a force of nearly one and a half tons.

In accordance with the measurements of the diameter and the mass of the sun, it follows that the average density of the material composing the sun is very much less than that composing the earth. In fact, it comes out that the sun's material is only 1.41 times the density of water, whereas the mean density of the material composing the earth is 5.5 times the density of water. Notwithstanding this remarkable fact, it has been shown by spectroscopic work that the heavy metallic elements, such as iron, nickel, zinc, tin, copper, and others, occur in the sun as well as in the earth. The explanation for the discrepancy of density between the two bodies lies probably in the very high tempera-

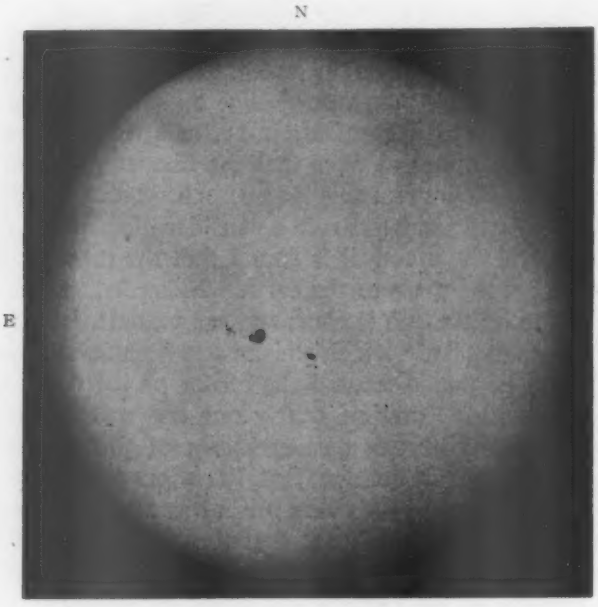
* Presented at the meeting of the Section of Physics and Chemistry held Thursday, January 8, 1914, and published by permission of the Secretary of the Smithsonian Institution.

Illustrations: Fig. 1 from *The Astrophysical Journal*, by permission of The University of Chicago Press. Figs. 2, 3, 4, 5, 6, 7, from Abbot's "The Sun," by permission of D. Appleton and Co.

ture of the sun, so that the elements found there are in the form of gases, whereas upon the earth they are in the form of solids. We shall return to this fact later.

As viewed through the telescope, the sun at first sight is a very disappointing object as compared with the moon. Nevertheless, there is much of interest to be seen there. In the accompanying figure we see a direct photograph of the sun as obtained by Slocum, of the Yerkes Observatory, on May 18, 1910. Several

FIG. 1.



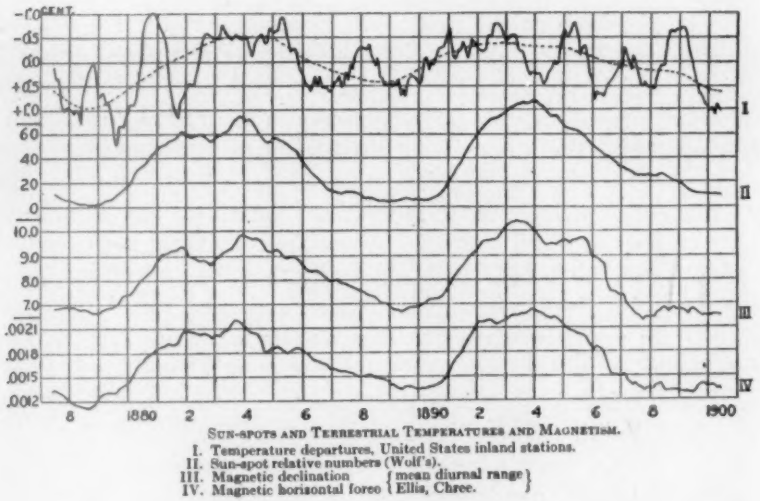
Direct solar photograph (Slocum).

interesting features may be pointed out. In the first place, note the falling off of the brightness of the disc toward the edges of the sun. In the second place, one sees in the original photograph all over the sun's surface a sort of mottled appearance, not very distinct, but yet interesting. In the third place, in this particular photograph, appear some dark spots, called sun-spots. Sun-spots were discovered by Galileo in the year 1610, soon after the invention of the telescope. They are distinguished by dark central parts, called the umbra, surrounded by a fringe of less

darkness called the penumbra. The spots shown in the present figure are very large ones, although they seem very small upon the surface of the sun. This is because of the immense diameter of the sun itself. The earth might be dropped into one of these sun-spots without much more than filling the umbra, leaving a generous space for the penumbra outside of it.

It was found by Schwabe, about the middle of the nineteenth century, that sun-spots occur most plentifully in periods of about 11 years between maxima. This may be seen by the accompanying figure, in which the second curve represents the prevalence

FIG. 2.



SUN-SPOTS AND TERRESTRIAL TEMPERATURES AND MAGNETISM.
I. Temperature departures, United States inland stations.
II. Sun-spot relative numbers (Wolf's).
III. Magnetic declination { mean diurnal range }
IV. Magnetic horizontal force { Ellis, Chree. }

of sun-spots according to the so-called sun-spot numbers published by Wolfer. The two lower curves represent respectively variations in the earth's magnetic declination and in the earth's magnetic force for the corresponding years. It will be seen how exactly the sun-spot curve is reproduced in these fluctuations of the earth's magnetism, but the cause of the connection which is so apparent is not yet well understood. In the upper curve of the figure are represented the departures of temperature for the average of 17 stations in the United States, and there will be seen, although not so plainly marked, an apparent influence of the sun-spots on the temperature of the earth.

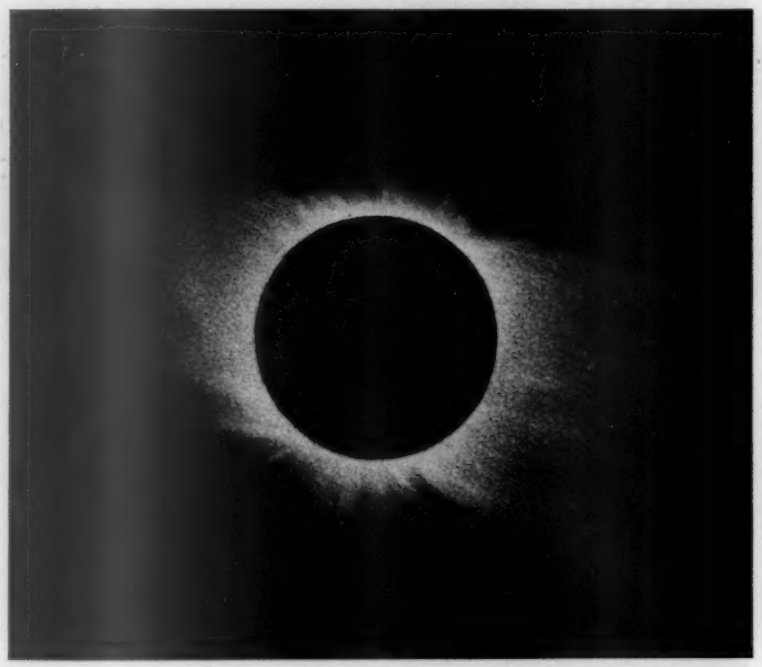
Recent work, much of it at the Mount Wilson Solar Observatory, has given us a good insight into the nature of sun-spots. They appear to be whirls of material coming outward from the inner layers of the sun toward the surface, spreading out there like a water spout. The expansion attending decrease of pressure on the gases causes a fall of their temperature, so that the sun-spots are cooler than the surrounding parts of the sun, and this is the reason why they seem dark. The whirling matter contains electrical charges, which, by virtue of their rotation, give rise to magnetic fields, as shown long ago by Rowland. The presence of magnetic fields in sun-spots has recently been established by Hale.

At certain times the moon interposes between the earth and the sun and cuts off the sunlight, so that we are able to see the objects which are surrounding the sun and usually lost by the intense glare of the sky. Such occasions are called "total solar eclipses." As the moon is but little, if at all, greater in angular diameter than the sun, the cone of shadow cast by the moon only a little more than reaches the surface of the earth, and sometimes, indeed, fails to reach it at all. When the cone reaches the earth's surface, and we have a total eclipse, there will be a belt, not more than two hundred miles wide, but sometimes several thousand miles long, upon the earth's surface, in which the total eclipse may be observed at some time of the day. Frequently the belt of totality passes over inaccessible regions of the earth, as, for instance, the North or South Pole, or falls upon parts of the ocean where it is impossible to use delicate instruments. The longest possible period of totality at any one station is 7 minutes, and in general the total eclipses average about 3 minutes in length. Thus only a very little time can be used in eclipse observations, and yet the information to be gained at such times is so valuable that observers often spend months in preparation, and travel thousands of miles to observe them.

The accompanying figures show the total eclipse of the sun. The first is from a drawing of Calvert as photographed by Yerkes Observatory observers at Wadesborough, N. C., in the year 1900, and the second is from a drawing by Mrs. Abbott from plates of the eclipse as photographed by the United States Naval Observatory parties in Spain and Africa, in the year 1905. In each photograph will be seen the corona, so-called, a pearly object

stretching out in beautiful forms to a considerable distance outside the sun. A great change, however, apparently occurred in its form between the year 1900 and the year 1905. This change is shown by other eclipse observations to be characteristic, and to always accompany the change from sun-spot minimum conditions to sun-spot maximum conditions. At sun-spot minima the solar

FIG. 3.



Solar corona, May, 28, 1900. (From drawing by P. R. Calvert from photographs by Yerkes Observatory Eclipse Expedition.)

corona extends in long equatorial streamers, while at sun-spot maximum the corona, though somewhat brighter, is not so extensive in any particular direction, but stretches almost equally in all directions.

Close up to the border of the sun there are also seen, at times of solar eclipses, bright red flames, called prominences, which are due to the gases hydrogen and calcium, with sometimes an admixture of other chemical elements. These beautiful objects

sometimes reach above the surface of the sun as much as 500,000 miles, and in some instances they have been observed to shoot up to such immense heights as this within 10 minutes of time. I say within 10 minutes of time, which implies that they may be seen at other times than during total eclipses. A method of observing them by aid of the spectroscope was devised independently by

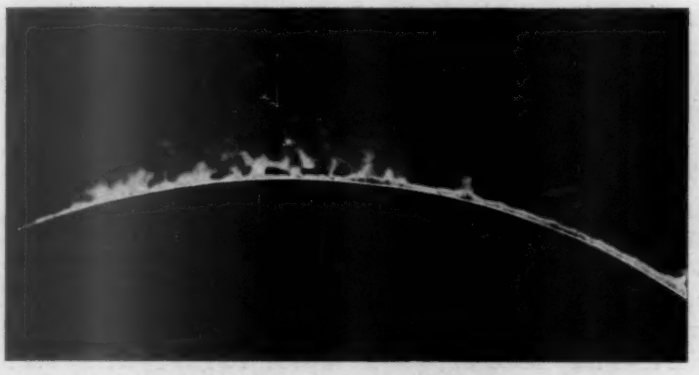
FIG. 4.

Solar corona. August 30, 1905. (From drawing by Mrs. C. G. Abbot from photographs by the United States Naval Observatory Eclipse Expedition.)

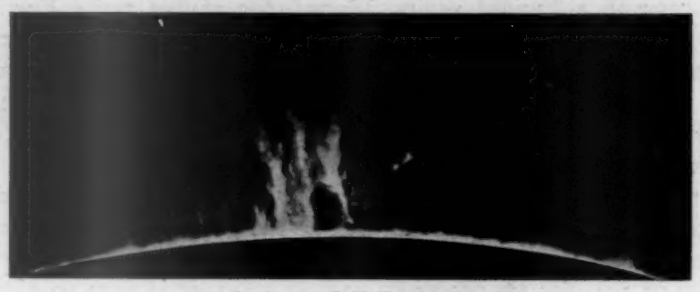
Lockyer and Janssen immediately after the eclipse of 1868, and nowadays many observatories examine them every day. A beautiful prominence is shown in the accompanying figures as photographed by Slocum at the Yerkes Observatory.

It would have seemed hardly credible to the contemporaries of Sir William, or even of Sir John Herschel, that the materials

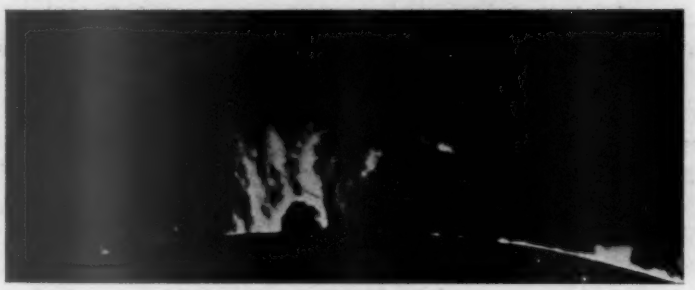
FIG. 5.



1910, March 17, G. M. T.; 5h. 30m.; long. 7°; lat. +17° to −18°.



1910, October 10, G. M. T.; 7h. 56m., .8.



1910, October 10, G. M. T.; 8h. 6m., .4.

Solar prominences (Slocum). Calcium (H) spectroheliograms.

of which the sun and stars are composed could ever be known, but by aid of the spectroscope much is learned in this respect. White light may be thought of as a complex mixture of vibrations

of the ether, so-called; that medium which is supposed to fill all space, including the interstices between the atoms and molecules of material bodies. When light passes through a prism of transparent substance, the complex vibrations are decomposed into their component parts, and we see the spectrum, in which the colors are arranged in the order, violet, indigo, blue, green, yellow, orange, red. The spectrum is by no means limited by the end of the visible red, or by the end of the visible violet, for rays which may be photographed, and which produce heat when allowed to shine upon blackened substances, exist both beyond the red and beyond the violet. Those beyond the red are called infra-red, and those beyond the violet, ultra-violet. The ultra-violet rays may be readily photographed, and by specially staining photographic plates, with organic dyestuffs, it is possible also to photograph a limited region beyond the visible red. Further progress in that direction, however, must be made by delicate electrical thermometers, or other heat-measuring instruments.

When the chemical element sodium or any of its compounds, like common salt, for instance, is placed in the flame, and the light which is given out is examined in the spectroscope, it is seen to consist of a couple of bright yellow lines. No general extension of the spectrum to include the green or violet is seen. On the other hand, if one observes the spectrum of the lime-light or the electric arc from carbon poles, it is seen to give a long band of color much like the solar spectrum, except that, whereas in the solar spectrum a great number of dark lines are seen under good conditions, in the spectra of the arc light or of the lime-light these lines will generally be absent. If, however, the vapor of metallic sodium be caused to intervene between the source of light and the slit of the spectroscope, two dark lines will be seen in the yellow, corresponding in position to the two bright yellow lines which are found by observing the light from heated sodium, or heated common salt. In short, the yellow light is absorbed by the sodium vapor at the very positions in the spectrum where that vapor would itself give off light if strongly heated. The same is true of iron and other metals. The spectrum of iron is very complicated, consisting of a great number of lines, many of them in the green. If the arc light be caused to play between iron poles, these bright green lines will be the main features of the light as observed in the spectroscope. Some of these lines are

very strong, others quite weak, so that there is often a well-marked distinction between one line and another, not only as regards its place but also as regards its intensity in the spectrum.

Now it is found on observing the spectrum of the sunlight or starlight that the dark lines are found in the same relative positions, and generally of nearly the same relative intensity, as in the bright line spectrum of the chemical elements themselves. In this way it is possible to determine what elements are found in the sun and the stars, although these bodies are so immensely distant from us. In this way we know that more than forty of the ordinary chemical elements found upon the earth exist also in the sun, and the existence of about twenty more is doubtfully indicated by the solar spectrum. Not only does the approximate correspondence in position and intensity of the spectrum lines of the sun and of the chemical elements as observed in the laboratory yield this significant result, but the slight deviations from exact correspondence in intensity and in position of the spectrum lines yield other facts not less remarkable. For instance, it was predicted by Doppler and observed in the laboratory by Prince Galitzen that the motion of a source of light toward the observer displaces its spectral lines toward the violet, and, contrawise, the motion of the source of light away from the observer displaces the spectral lines toward the red. This effect is very noticeable in the solar spectrum if one takes the light from the east and west limbs of the sun. There is a displacement of the lines of the two spectra with respect to one another, depending upon the fact that the one side of the sun is approaching the earth and the other side receding, by virtue of the rotation of the sun on its own axis.

It had long been known that the sun rotated upon its axis, because of the behavior of sun-spots, which march across the disc of the sun in a period of about fourteen days.[1] Duner, Halm, Adams, and others have observed the rotation of the sun by means of the displacement of the spectral lines. The curious fact that the surface of the sun rotates with unequal velocities, largest at the equator and smaller as we approach the poles of the sun in either direction, had been noted from sun-spot observations. This

[1] This exceeds the half-period of the sun's rotation because of the advance of the earth in its orbit at the same time.

peculiar rotation behavior of the sun's surface was investigated much more thoroughly by Adams, who followed the rotation of the sun up to solar latitude of 75°. He found that the period of rotation, as determined by the majority of the spectrum lines, varied from 24.6 days at the equator to 33.1 days at latitude 75°. However, the element hydrogen, which is situated high up in the solar atmosphere, indicated a much more nearly equal velocity of rotation at differing latitudes. The values range from 23.7 days at the equator to about 26 days at latitude 75°.

Another cause of the displacements of the spectral lines is in the pressure which exists in the solar envelope. This was investigated first by Humphreys and Mohler at Baltimore. It has since furnished a valuable means of measuring the pressure which exists in the solar envelope. For the element iron it is found to be about five times the atmospheric pressure at the surface of the earth.

Still another interesting displacement of spectral lines was found by Zeeman to be due to the presence of a magnetic field. Spectrum lines are broken up in the presence of a magnetic field into doubles or triples or still more complex groups, whose complexity of arrangement depends upon the situation of the spectroscope with respect to the magnetic field, and on the strength of the magnetic field in which the light is produced. This peculiarity was taken advantage of by Hale, who has recently proved the existence of a magnetic field in sun-spots, and still more recently the existence of a general magnetic field over the whole surface of the sun, analogous in many respects to the magnetic field which exists over the surface of the earth.

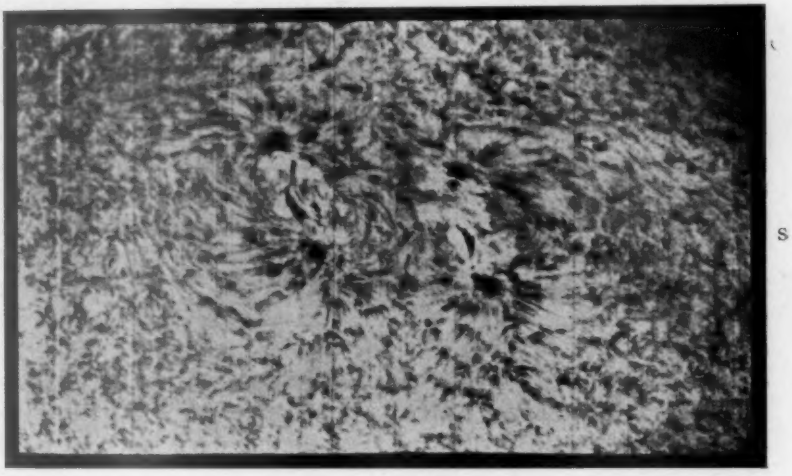
A brilliant invention of Hale's earlier years of investigation was that of the spectroheliograph. This is an instrument for observing the sun's disc in the light of a single line of a single chemical element. It is not necessary here to explain the details of the construction or the principle of it, more than to say that it is a particular form of spectroscope whose effect is to act as a screen to cut off all rays of the spectrum except the particular one which it is desired to observe. By the aid of this instrument the distribution of the gases of different elements over the sun's disc has been investigated, notably of the gases hydrogen and calcium. The accompanying illustration shows a photograph of a portion of the sun's disc as observed in hydrogen. The reader

will note the very prominent detail which is shown by this illustration as compared with that shown by direct photography of the sun's surface by a telescope as given in Fig. 1. It was by the aid of the spectroheliograph that Slocum obtained the beautiful figure of the solar prominence given in the preceding illustration.

SOLAR ENERGY.

We now turn from this general consideration of what may be seen on the sun by the aid of the telescope and spectroscope

FIG. 6.



Hydrogen spectroheliogram, Ha (Ellerman). 1909, September 10, G. M. T.; 3h. 22m. P.S.T 7h. 22m. A.M.

to a discussion of the quantity of energy which the sun sends out, the distribution of it among the different spectrum rays, and the relations which it bears to the temperature of the sun, the temperature of the earth, and other terrestrial concerns. I said a little while ago that light is regarded as of the nature of a mixture of vibrations in the ether, which is supposed to be a substance existing in all space, including the interstices of the structure of the chemical elements themselves. Light is but one of the manifestations of radiation. It is merely that kind of radiation

which is visible to the eye. Just as there are some sounds which are of too high pitch for the ear to hear, and some other sounds which are of too low pitch to distinguish as sound, so there are kinds of radiation which are of too short wave-length for the eye to recognize as violet light, and others are of too long wave-length for the eye to recognize as red light. Indeed, for the longer wave-lengths of radiation the substances of the eye are not transparent, so that even if the retina should be sensitive to these rays, they could not reach the retina to effect it.

In this state of affairs it is necessary to proceed to the investigation of the energy of radiation by means of another instrument in which the radiation is caused to be absorbed by a blackened surface, and thus to produce heat, and consequently a change of temperature of the absorbing substance. Radiation is not heat. Heat is a motion of the molecules of the material substance, but radiation is a motion of vibration in the ether, which is not regarded in the same category with ordinary chemical elements. Indeed, we may go a little further and make a classification of energy. Imagine a chest of drawers in which, as sometimes happens, the letters or other papers fall over the back of the drawers, as they are pulled out, into the ones below. It is easy in that manner for the papers in the upper drawers to fall into the lower drawers, but work has to be done in order to get the papers from the lower drawers into the upper ones again. So with energy: all forms of energy may easily be transformed into heat, which is the lowest type of energy, but heat energy can only partially be transformed back again into the higher types. Of these types radiation is one of the very highest.

Now it is on the sun's radiation that a temperature suitable for life upon the earth depends. Not only that, but the peculiar properties of certain wave-lengths of the solar radiation are required for supporting plant growth, with its complex chemical reactions. All sources of energy upon the earth have been directly or indirectly produced by solar radiation. A good many investigators, among them Mr. Shuman, of Philadelphia, have endeavored to use the solar radiation commercially for the production of power, and, in fact, very satisfactory results are being obtained in this way, under Mr. Shuman's direction, from a plant in Egypt.

Evidently it is of the greatest interest to measure the quantity

of the solar radiation, the distribution of it in the spectrum, the hindrances which it suffers in passing through the earth's atmosphere, and the quantity of it available to warm the earth after it reaches the surface. This has been the principal work of the Astrophysical Observatory of the Smithsonian Institution for the last twelve years.

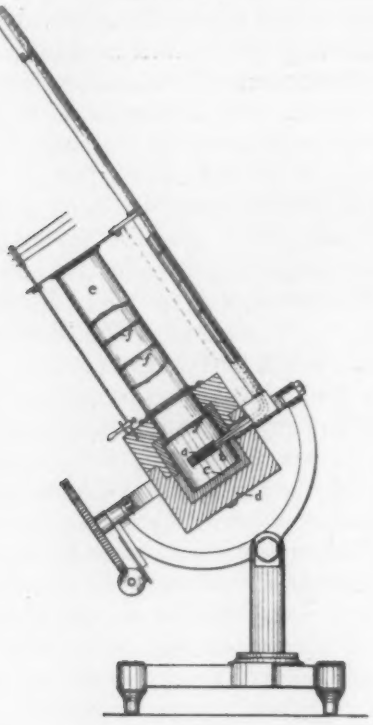
In the first place, we have to deal with the measurement of the solar radiation as a whole. For this purpose we employ what is called the pyrheliometer, a name first devised by Pouillet, about the year 1835. He employed a blackened box, filled with water, and containing a thermometer for observing the rise of temperature in the water due to the absorption of the solar rays upon the blackened box. In our practice we have considerably developed the instrument of Pouillet, until now it comprises a silver disc enclosed in a chamber provided with a vestibule for the admission of the solar rays. The disc has inserted in it a thermometer, which is bent at right angles for convenience, and on which the rise of temperature of the silver disc due to the absorption of solar radiation is observed. The instrument is shown in the accompanying illustration (Fig. 7).

It is not possible to obtain the correct heat capacity of the pyrheliometer in this form, so that we have reduced its measurements by comparison with what is termed the standard pyrheliometer, in which the heat produced by the sun's radiation is carried off by flowing water. The rise of temperature in the water, due to the absorption of the solar radiation, is determined by means of an electrical thermometer. In this apparatus it is possible to introduce electrically known quantities of heat, and to measure them as if it was solar radiation which was being measured. In such test experiments it is found that as much as 99 per cent. of the heat introduced is recovered, and it is believed that the standard pyrheliometer gives the true scale of radiation for the sun within a probable error of a half of one per cent. The silver disc pyrheliometers have been compared against this standard, and in this way the standard scale of radiation has been diffused by the Smithsonian Institution, which has sent out about 25 copies of the standardized silver disc pyreheliometer to various countries of the world, in Europe and North and South America.

Measurements with the pyrheliometer indicate that the maximum intensity of the sun's radiation at sea level is about 1.5 calo-

ries per square centimetre per minute. At high-level stations, such as Mount Whitney, in Southern California, at an altitude of 14,500 feet, the readings run as high as 1.7 calories per square centimetre per minute. You may ask why it is that if the intensity of the sun's radiation increases as we go up a mountain, it should be also the case that the temperature of the air at high elevations

FIG. 7



Silver disk pyrheliometer.

is lower than it is at sea level. This is due to the property of the air of almost freely transmitting solar radiation. Like a pane of glass in a window, it is not much warmed by absorbing the rays, whereas a blackened substance held in the beam of light, either upon a mountain or inside the window pane, will be very appreciably warmed.

If we could go outside the atmosphere altogether, all the

radiation which we receive from the whole sky, and which is derived by scattering, would be still in the direct sun-beam. Looking away from the sun we should see the stars shining, as if at night, and the sun's rays themselves as observed by the pyrheliometer would exceed in intensity even those observed on high mountain summits. Now the question is, What would be the intensity of the solar radiation if we could observe it outside the atmosphere, at the earth's mean solar distance? This quantity is called the solar constant of radiation, and it has been an object of investigation for the last hundred years.

As shown by Forbes, Radau, and notably by Langley, it is not possible by means of the pyrheliometer alone to estimate what the intensity of the solar radiation outside the atmosphere would be, unless the pyrheliometer itself could be raised by a balloon or otherwise to the extreme limit of the atmosphere. This latter procedure having heretofore been impracticable, it was necessary to have recourse to measurements of the solar spectrum. The defect in pyrheliometer observations consists in this: that the several rays of the solar spectrum are unequally affected in passing through the earth's atmosphere. Certain rays are almost completely removed in the higher levels of the atmosphere, so that we can by no means estimate the losses, even upon the highest mountains, unless recourse is had to determinations in the spectrum.

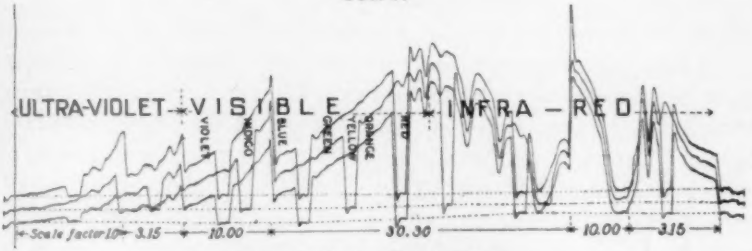
About the year 1880 the late Dr. Langley invented the bolometer. This is an electrical thermometer of great sensitiveness. It comprises two fine strips of platinum, each about one-half inch long, one-two-hundred-and-fiftieth of an inch wide, and one-two-thousandth of an inch thick. The strips are blackened on the front surface with smoke, or with platinum-black electrically deposited. These two strips, with two coils of resistance wire, form a Wheatstone's bridge, so-called. If one strip is warmed with respect to the other, and thereby its electrical resistance is increased, the effect is to cause a slight current of electricity to flow through a very sensitive galvanometer. In ordinary practice one can detect with the bolometer differences of temperature of a millionth of a degree; and in the most refined construction, with every precaution taken to avoid disturbing influences, it has been possible to observe the hundred-millionth part of a degree change of temperature.

With the bolometer, which in those days was an instrument of very uncertain behavior, and one requiring the most expert attention and great patience for its use, Langley observed the sun's spectrum in the famous expedition of 1881 to Mount Whitney, in Southern California. Like early investigators who had used the pyrheliometer alone, he observed the increase of the intensity of the sun's rays from early morning to noon, and their decrease of intensity from noon until late afternoon. This depends, as you will see, upon the fact that when the sun is low and near the horizon it shines obliquely through the atmosphere, so that its path in the air is very long, whereas at noon, when the sun is nearly overhead, the path in the air is comparatively much shorter. If one observes, therefore, the intensity of each of the spectrum rays at different altitudes of the sun, for which he knows the length of path in air, he may compute from the observed increase of intensity, attending the decrease of air path, how much the intensity would be if the path in air could be reduced to nothing at all, or, in other words, if he could go outside the air altogether. It is not possible to do this by observation with the pyrheliometer alone, as explained above, because the rays of certain spectrum wave-lengths are almost entirely removed in the upper atmosphere, and do not reach the observer at all, even if he be on a high mountain. Especially is this the case in the infra-red region of the spectrum, which is invisible to the eye, but which is of great importance as containing a large part of the sun's energy. In this region there are great water-vapor bands, where the water vapor of the atmosphere almost completely absorbs the solar rays, leaving great gaps in the representation of the sun's energy spectrum. Langley introduced the procedure of estimating for all other parts of the spectrum the intensity which would be found outside the atmosphere, but in the great water-vapor and other terrestrial bands of absorption he merely made the assumption that these would be altogether absent if he could in fact be beyond the atmosphere altogether.

After Langley became Secretary of the Smithsonian Institution he established the Astrophysical Observatory there, in order that he might carry out to greater perfection the measurements of radiation begun by him while still Director of the Allegheny Observatory in Pennsylvania. Among the first improvements introduced in Washington was the automatic recording of the results

of the bolometer by photographic means. This was a great step, so that now we are able, in the lapse of less than ten minutes, to observe the intensity of the rays of the sun of all wave-lengths, from those far beyond the violet end of the visible spectrum to those far beyond its extreme red. The accompanying figure shows the result of three such observations made on Mount Wilson, in California, at the station of the Smithsonian Institution there. These three curves represent the distribution of solar radiation in its spectrum, including the ultra-violet, visible, and infra-red rays. The great water-vapor bands above mentioned are shown in the infra-red as great depressions of the curve. Solar absorption lines are shown in the visible spectrum as smaller depressions of

FIG. 8.



Bolographs of the solar spectrum.

Air masses of observations { Upper curve, 3.0. Middle curve, 4.0. Lower curve, 5.2.

the curves. The three curves were taken at different hours of the morning, when the path of the solar rays in air was five, four, and three times, respectively, that which would occur if the sun were vertically overhead. The reader will notice that the curves are respectively higher and higher, especially in the violet end of the spectrum, owing to the decrease of the length of path of the sun rays in the air. At several points a change of scale of the curves is shown. This is due to the introduction in the beam of rotating sectors of different angular apertures in order to keep the record always within the limits of the registering photographic plate. If these changes of scale had not been made, the curve would run up in the edge of the red to the height of the room.

By suitable computation, by the aid of the exponential formula developed by Bouguer about the year 1760, it is possible to compute for each of the parts of this spectrum energy curve the

intensity which would be found if one were outside the air altogether. In this way one might construct a curve similar to the three shown in the illustration, which would represent the intensity of radiation beyond the limits of the atmosphere. In such curves as these the area included between the curve and the axis of zero radiation is proportional to the intensity of the whole solar beam, including all wave-lengths. This, of course, is also measurable by the pyrheliometer. Accordingly we multiply the reading of the pyrheliometer by the ratio between the area of the curve outside the atmosphere and that which is found at the observing station, and thereby we obtain the solar constant of radiation. In this process, however, we follow Langley's assumption that there will be no absorption by water vapor or oxygen in the sun itself, and therefore draw a smooth line, in our extra-atmospheric energy curve, where great atmospheric bands occur.

About 700 determinations of the solar constant of radiation have been made by the Astrophysical Observatory of the Smithsonian Institution, some at Washington at sea level; others at Mount Wilson, at an elevation of about one mile above sea level; others at Mount Whitney, at an elevation of nearly three miles; and others at Bassour, Algeria, at an elevation of three-quarters of a mile. No differences beyond the reasonable errors of measurement are found between observations made at two stations on the same day, whether made at sea level or at any of these stations, up to the elevation of Mount Whitney, 14,500 feet above sea level. Hence it appears that the method of estimating atmospheric transmission is probably sound. The mean value of the solar constant of radiation, as thus found from 700 determinations, is 1.933 calories per square centimetre per minute. By this is meant that if the sun's rays outside the atmosphere could be absorbed completely in a layer of water one centimetre (about three-eighths of an inch) thick, exposed at right angles to the solar beam, this layer of water would be warmed 1.93° C. during each minute of time. Expressed in another way, the sun's radiation outside the atmosphere would be able to melt a layer of ice 105 feet thick each year.

An extremely interesting feature of the measurements has been that they show a variation of the sun. This conclusion has been tested in every way, not only by making measurements at different altitudes, but by comparing results obtained on the same

days at Mount Wilson, in California, and at Bassour, Algeria. As these stations are separated by about one-third the circumference of the earth, it seems not possible that they could be generally influenced by local conditions in a way to disturb the measurements in the same direction at the same time. Nevertheless, the results of about 50 days of simultaneous observing at the two stations agree in showing that when the radiation of the sun is found above the normal, at the one station, it is found also above the normal at the other station, and *vice versa*. The fluctuations of the intensity of the sun's radiation outside the atmosphere thus indicated range over about ten per cent. Often within a single week, or ten days, a fluctuation of radiation as great as five per cent. is shown. The variation of the sun in these short periods appears to be irregular, both as regards the magnitude of the variation and as regards the period of it.

The measurements made at Mount Wilson, which extend over the years 1905 to 1913, indicate also a fluctuation of the intensity of solar radiation, attending the changes of the number of sun-spots. There appears to be about three per cent. increase of the solar radiation outside the atmosphere, for an increase of 100 in the Wolf sun-spot numbers. It is a very curious thing that the solar radiation increases with increasing numbers of sun-spots, whereas the temperature, which directly depends upon the solar radiation, falls with increasing numbers of sun-spots. It appears that there is, attending sun-spots, a direct and an indirect influence on terrestrial temperature. The direct influence is due to the increased solar radiation. The indirect influence is perhaps due to a change in cloudiness, but as yet is not certainly understood. These two influences are of almost equal magnitude in general, but with the indirect influence, which tends to lower temperatures, slightly predominating. It will be a research of great interest and value to determine the cause of the indirect influence.

In connection with these researches on the solar radiation the transparency of the air for light of all colors, and for invisible rays, has been determined. This is a matter of great interest to those who are studying the growth of plants, as well as to those who are interested in the propagation of signals by means of lights at sea and elsewhere.

Also, the form of the energy spectrum of the sun having

been determined, it is possible to estimate the probable temperature which exists in the sun. For it is shown that as the temperature of a source of light increases, the position of the wave-length of maximum intensity in its spectrum shifts toward the violet end of the spectrum, and from the exact position in the spectrum of the wave-length of maximum intensity the temperature of a source of light may be ascertained. In this way it appears that the sun's temperature is of the order of 6000° C., or nearly twice the temperature of the arc light. It is also possible, by means of the measurement of the solar constant of radiation, to determine the sun's temperature. In this way also values of the order of 6000° C. are found.

The surface of the sun is not equally bright from one edge to the other. This is shown plainly on solar photographs, as was pointed out in relation to the first illustration, but a more careful study of the matter is being made by the Astrophysical Observatory of the Smithsonian Institution, at its station on Mount Wilson, by the aid of the bolometer. The accompanying figure (Fig. 9) shows the observing station of the Astrophysical Observatory, and the reader will see a tower which has been erected upon it, in which is a vertical telescope for forming a large image of the sun. By stopping the clockwork, this image is allowed to drift across the slit of the spectro-bolometer. Thereby an automatic record is produced of the distribution of radiation of any selected wave-length from one edge of the sun along the diameter to the opposite edge. Such observations are shown in the accompanying illustration (Fig. 11). The distribution of radiation is given for five different wave-lengths.

It is seen that there is a marked contrast of brightness, especially for violet rays. Here the edge of the sun's disc is hardly half as bright as the centre. The contrast of brightness diminishes with the increasing wave-length of the light examined, and for the infra-red rays is comparatively small. Experiments are being made on every day on which the solar constant of radiation is determined, in order to see if there is a change of contrast in brightness along the diameter of the sun, accompanying the change of the intensity of the sun's radiation. Changes of contrast along the sun's diameter have already been found, but it is not yet decided whether they agree in point of time with the changes in the intensity of the solar radiation.

NATURE OF THE SUN.

In view of what has been said, what is the nature of the sun? It appears, in consideration of its high temperature and low density, to be a great ball of incandescent gases. Of course, the pressure is so enormous that the gases approach the density of liquids. These gases are so hot as to exceed in temperature any-

FIG. 9.

Smithsonian observatory on Mount Wilson.

thing that we have upon the earth's surface. It must not be supposed, however, that they are burning gases like the burning of illuminating gas in air. The temperature on the sun's surface is so high that in general no compounds of elements are occurring there. If the ordinary compounds, for instance, products of combustion like carbonic acid gas, should be present on the sun, the elements of which they are composed would separate, one from another, owing to the enormous temperature. As the sun

gives off radiation, it tends to cool, and it may well be asked why, in the course of the millions of years which geologists tell us have elapsed since the earth reached substantially its present temperature, the sun should not have cooled off entirely. A partial source for this immense quantity of energy was suggested by Kant and discussed at length by Helmholtz, who showed that the enormous gravitation of the sun, tending to condense the gases, and bring them toward its centre, must, for every decrease of

FIG. 10.

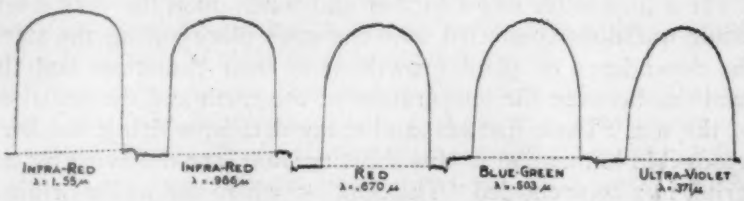
Smithsonian observatory on Mount Whitney.

temperature and consequent shrinking up of the volume of the sun, produce a certain quantity of energy. This source of the sun's energy, however, seems insufficient to account for that which geologists demand us to concede. It may be that the secret of the matter is in the breaking up of the atoms, such as is now found to occur with the element radium.

If the sun is gaseous, the question naturally arises why it presents so sharp and round a boundary. The roundness of the sun is only what would be expected in view of its gravitation.

The sharpness of its boundary seems explainable as follows: Gases, although very transparent, are not perfectly so, so that in the case of the earth the atmosphere above Mount Wilson transmits only about 95 per cent. of the yellow light. If, then, 5 per cent. of the sun's radiation in the yellow is cut off by the earth's atmosphere, it follows that a layer of the sun's gases only a few thousand miles thick would be sufficient to prevent us from seeing any deeper. This three or four thousand miles of thickness, as we look at the centre of the sun, will extend vertically downward, but at the edge of the sun we look obliquely, and there the three or four thousand miles will all be found in a layer of the sun perhaps not more than a hundred miles in thickness. In a body 800,000 miles in diameter a thickness of a hundred miles is

FIG. 11.



Brightness distribution along sun's diameter for different colors.

practically negligible, certainly so for any telescopic observations which can be made from the earth, hence, naturally, the boundary of the sun is seen to be sharp.

The contrast of brightness between the centre and the edge of the sun follows at once from what has just been said. For at the centre we look far deeper than at the edge, and, naturally, see thereby gases which are much hotter than those which are perceived in the comparatively superficial layer which is seen at the sun's edge. Attending the increase of temperature there must be an increase of brightness, and this will be greater for red and infra-red rays than for violet and ultra-violet rays, in accordance with laboratory experiments on the relations of radiation and temperature. Thus the contrast of brightness between the centre and the edge of the sun will be greater in the red and infra-red than in the violet and ultra-violet.

The sun-spots appear to be whirlpools where the gases of the

interior are pouring out toward the exterior in forms similar to a water-spout. They are cooled by expansion as they reach the surface, and the partial vacuum formed in the centre of the whirl sucks in the superincumbent and very light gases, hydrogen and calcium, above the sun's surface. The magnetic field found by Hale in sun-spots is due, no doubt, to the rotation of the electrically-charged material in the spots. The solar spectrum, with its numerous dark lines, is due to the presence of the gases of the chemical elements which are found upon the earth. These gases are cooler at the boundary of the sun than they are within, where the principal part of the light comes from, hence, as noted above, the effect will be to produce dark lines on a bright background. The irregular mottled appearance of the sun's surface is probably due to differences of temperature which exist in so great a body, and thereby produce variations in brightness of different parts.

It is impossible to go further and touch upon the very interesting questions connected with the sun's place among the stars, the dependence of plant growth upon solar radiation, and the relations between the temperature of the earth and the radiation of the sun. These matters, and many details, which it has been impossible to mention in this short account, are discussed by the writer in a book entitled "The Sun," to which and to the original sources of information and to longer treatises the interested reader is invited to turn.

Crazing of Lead Glazes on Earthenware Bodies. J. A. CALLCOTT. (*Trans. Eng. Ceram. Soc.*, xiii, 49.)—Crazing may be caused by excess of some constituent in the glaze or body, by application of the glaze to too porous a body, or by incorrect firing. It is generally due to excess of soda in the glaze or of china clay in the body. Lime may be substituted for soda if opacity and dullness do not follow, a consequence which is avoided by rapid cooling from 1000° to 500° C., during which crystallization is most likely to take place. Cornish stone is a useful substitute for soda. China clay in the body may be replaced by Cornish stone or flint, or, if color be no object, by ball clay. Substitution of buff for purple Cornish stone in the body may be a cause of crazing. The function of flint is to alter the coefficient of expansion and to promote chemical combination between clay and fluxes. Vitreous bodies, usually deficient in flint, are especially liable to exhibit crazing. If the mixings are unaltered, a higher temperature or more prolonged firing is required.

THE SUBSTITUTION OF METAL TAPES AND WIRES FOR BARS IN BASE MEASUREMENTS.*

BY

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ALL of you are familiar with the fundamental principle that it is necessary, in any accurate survey, to have the relative positions of some points known. When the area surveyed is of limited extent the positions of the controlling points may be determined by traverses of various degrees of accuracy, depending on the purpose of the survey.

When the survey is to be extended over great areas or over long distances, such as a state or a long stretch of the coast or of a river, the controlling points must be determined by the method called triangulation. It rests upon the mathematical principle that when three elements of a triangle are known, at least one of which is a side, the other three can be computed.

The usual procedure is to measure one side of a triangle as a base; then, from the observed angles of the connected scheme of triangles, compute all of the other sides through the system, using for the base of each triangle, except the first, a computed length.

It is usual, in extensive triangulations, to have direct measurements of more than one triangle side to strengthen the computed lengths and to guard against gross errors.

After the scheme of triangles has been adjusted for the accidental errors of the angles and the discrepancies in lengths between bases, the latitude and longitude of each point and the true bearing (or azimuth) of each line are computed from some initial station. For all connected triangulation in the United States, Canada, and Mexico, the initial point is the triangulation station, Meades Ranch, in the State of Kansas. Its adopted latitude and longitude and the azimuth from it to the station Waldo are called the North American Datum. The geographical positions are referred to the Clark spheroid of 1866, as expressed in metres. Its dimensions are: Equatorial radius, 6,378,206 metres; polar semi-diameter, 6,356,584 metres; reciprocal of flattening, 1/295. This spheroid has been found to be so near the true size of the earth that, for geographical and engineer-

* Communicated by the author. Read December 30, 1913, before Section D, American Association for the Advancement of Science, Atlanta Meeting.

ing purposes in this country, it is believed that no other one need ever be substituted for it. Therefore, when a triangulation station has been computed on this spheroid and on the North American Datum its position may be considered final.

Triangulations are usually classified as primary, secondary, and tertiary, according to their relative accuracy. No longer is a triangulation classified according to the size of the triangles involved. Primary triangulation is used in extending the fundamental control over the country and in connection with accurate city surveys, such as those of New York and Cincinnati. In this class of triangulation the accuracy is that represented by an average closing error of about one second; that is, the three measured angles of a triangle will, on an average, fail to add up to 180° by only one second. Of course, in large triangles the spherical excess is considered. The direct measurement of those sides of the triangles used as bases has been a difficult problem for surveyors and geodesists until recent years. At present, the bases can be measured with great accuracy by means of tapes or wires made of the alloy of nickel and steel called *invar*.

Among the earliest forms of measuring apparatus used were wooden bars and glass tubes. These were not very satisfactory and they gave way gradually to metal bars, which apparently were first used in 1788 in Italy, and a little later, in 1798, in France.

The bars were usually made of steel or brass and they maintained their lengths most satisfactorily, but the great difficulties involved were the determination: (1) Of their exact lengths in terms of some standard unit, at some given temperature; (2) of the amount of change in length for a given change in temperature; and (3) of the exact temperature of the bars during the field measurement. The first difficulty was overcome by standardizing the bars in a room which could be maintained at a constant temperature and the coefficient of expansion was determined by standardizing the bars in the room at widely different temperatures. I believe it may be stated, without fear of successful contradiction, that the temperatures of no set of single-rod base bars of brass or steel were ever obtained during field measurements in daylight with a high degree of accuracy. Many methods of insulating and protecting the metal rod were employed, but the temperatures read from the mercurial thermometer inserted in the case did not correctly indicate the actual temperature of the rod.

A base measured with single brass or steel rod bars, with a small probable accidental error, might have a large actual error. As an example, a base measured by a set of these bars in Colorado, with a probable accidental error of only one part in 752,000, was this year remeasured with invar tapes and the difference in the two lengths was one part in 59,000.

It is probable that steel or brass single-rod bars would give more accurate results if used only on cloudy days or if they were used at night, when the temperature is apt to be more constant, for then the temperatures given by the thermometers would be more nearly those of the bars. But cloudy days in some regions are not numerous, and to have measured a base at night would have been a difficult and tedious undertaking.

In order to minimize or eliminate the effect of errors in temperature, various compound bars were devised. One type consisted of two parallel rods of different metals, such as platinum and copper, or steel and brass, the two rods of a bar having very different rates of expansion. Theoretically the average temperature could be obtained by noting the difference in length of the two components, which were arranged with suitable scales for making the comparison. This principle of differential expansion was applied in several different ways.

Other compound bars were designed to give a constant length by a compensating arrangement of the components.

Excellent results were obtained with the Bache-Wurdemann compensating bars of the U. S. Coast and Geodetic Survey, but it was found that slightly different results were obtained with rising and with falling temperatures. This trouble was minimized by having the bars standardized under each condition. The Eimbeck duplex bars of the Survey also gave a high degree of accuracy in the measurements, but they were used only a little, as the use of the tapes was begun shortly after they were made.

In the field measurements the bars were supported by portable tripods. The bars were either "line measures" or "end measures." In the first type, the length of the bar is the distance between two very fine lines engraved on the top of the bar near its ends. The successive bar lengths were referred to powerful microscopes mounted on posts set along the line of the base. In the "end measures" the length of the bar is the distance between its ends, and the procedure was to set two bars end to end and then move the rear one ahead and bring its rear end into

contact with the forward end of the bar left in place. In one of the earliest methods of measuring, the two bars were brought nearly together, and the distance between them was measured by a wedge properly graduated and standardized. The wedge was inserted between them and the points of contact of the bar ends on the wedge would enable the distance between the bars to be determined accurately. These small distances would be added to the whole number of bar lengths as set ups. The usual and better method of making the contact of the two bars was to have a sleeve fit over one end of each bar, the sleeve being connected with the bar by a spring. The bar was normal when a graduation on the sleeve coincided with a graduation on the bar. A slow-motion device enabled the operator to move the forward rod in its case until the contact with the rear bar was perfect and the two graduations on the bar and sleeve coincided. This procedure was repeated throughout the length of the base.

The only bar used in the United States, and probably in the world, which will give entire satisfaction in so far as accuracy is concerned, is a "line measure" called the "iced-bar apparatus" of the Coast and Geodetic Survey, which was designed by Dr. R. S. Woodward.[1] During measurements this bar is placed in a trough which is filled with crushed ice. Thus the bar is kept at a uniform and definite temperature, that of melting ice. Of course, measurements cannot be made when the temperature of the air is below the freezing-point. The trough is mounted on a carriage which runs along a portable track. The successive bar lengths are referred to microscopes placed on posts set along the base. The cost of using this bar is great and it has been and is now used only for the purpose of standardization of other apparatus, and for this it is unexcelled.

Steel wires and tapes were used in general surveying long before they were used for the measurement of primary base lines. They were, apparently, first used successfully for bases by Professor Jäderin, of Sweden, about 1882.[2] Tapes were experimented with at the Holton Base, Indiana, in 1891,[3] and

[1] Described in detail in Appendix 8 of the Coast and Geodetic Survey Report for 1892.

[2] See Appendix 5, Coast and Geodetic Survey Report for 1893.

[3] See Appendix 8 of the Report of the Coast and Geodetic Survey for 1892. See also Appendix 3 of 1901, Appendix 4 of 1907, and Appendix 4 of 1910, for the history of measurements of primary bases with tapes, by the Coast and Geodetic Survey.

found to be as accurate, when used at night, and much more economical than bars. Tapes were used in 1893 and 1897 in measuring the bases at St. Albans, W. Va., and at Versailles, Mo. In 1900–01 steel tapes of 100-metre and 50-metre lengths were used in connection with the Eimbeck duplex bars in the measurement of nine primary bases on the 98th meridian. One-fifth of each base was measured with the bars, and at each base 1 km. was measured with the bars and each of the tapes. The result of this campaign proved conclusively that the tapes used at night gave an accuracy as great as that obtained with the best bars.

In 1906 the Survey tested tapes made of the alloy of nickel and steel (called *invar*) by measuring six primary bases with both steel and invar tapes. The invar tapes gave results of even greater accuracy than the steel tapes, although the former were used in daylight, while the latter were used at night. All of the tapes were 50 metres in length, this length having been found more satisfactory than 100-metre tape during 1900–01.

The average coefficient of expansion of the invar tapes used by the Survey is only .0000004 per degree Centigrade, or about one-twenty-fifth that of steel. Having available a metal with such a low coefficient of expansion, the great problem in base measurement has been solved. Bars of this metal would no doubt give a measurement almost without error, but invar tapes give results which have actual errors little or no greater than one part in one million, and, as a base can be measured with tapes for 35 per cent. or less of the cost of bar measurements, it is practically certain that no more base lines will be measured with bars. Tapes have the additional advantage that they may be used over broken ground and steep slopes where bars could not be used.

That invar tapes hold their lengths in a remarkable manner is indicated by the data in the following table for tapes which have been used on all primary bases measured in 1909 and later by the Coast and Geodetic Survey. The lengths given result from six standardizations at the Bureau of Standards.

SUMMARY OF TAPE VALUES.

The following is a table showing, for each of the four tapes, the length as determined by six different standardizations, the probable error of each determination, the mean of the results from the six standardizations and the residuals. The values given are for the lengths of the tapes when resting upon three

points of support and subjected to a fixed tension of 15 kilograms. In order to make the values comparable, they have all been reduced to a common temperature, namely, 21.2° C.

VALUES OF TAPES WITH THREE SUPPORTS
At temperature of 21.2° C.

Date of standardization.	T_{816} =		T_{817} =	
	50m. +	v	50m. +	v
	mm. mm.	mm.	mm. mm.	mm.
January, 1909.....	9.542±0.017	−0.044	9.735±0.018	+0.081
May, 1909.....	9.454±0.028	+0.044	9.782±0.025	+0.034
March, 1910.....	9.415±0.017	+0.083	9.738±0.015	+0.078
March, 1912.....	9.473±0.029	+0.025	9.869±0.022	−0.053
January, 1913.....	9.519±0.016	−0.021	9.919±0.016	−0.103
October, 1913.....	9.587±0.020	−0.089	9.853±0.017	−0.037
Mean.....	9.498	.....	9.816	.....

Date of standardization.	T_{821} =		T_{822} =	
	50m.+	v	50m.+	v
	mm. mm.	mm.	mm. mm.	mm.
January, 1909.....	9.750±0.018	+0.175	10.543±0.019	+0.068
May, 1909.....	9.835±0.021	+0.090	10.566±0.024	+0.045
March, 1910.....	9.878±0.015	+0.047	10.593±0.018	+0.018
March, 1912.....	10.009±0.021	−0.084	10.644±0.017	−0.033
January, 1913.....	10.034±0.016	−0.109	10.664±0.016	−0.053
October, 1913.....	10.047±0.018	−0.122	10.655±0.020	−0.044
Mean.....	9.925	.....	10.611	.....

This table gives very valuable data as to the constancy of the lengths of the invar tapes. The total ranges for four years in the lengths of the various tapes are:

Tape No.	Total range, mm.	Proportion.
T_{816}	0.172	1 part in 290,000
T_{817}	0.184	1 part in 270,000
T_{821}	0.297	1 part in 170,000
T_{822}	0.121	1 part in 410,000

The differences in length between the values resulting from the first and last standardizations are:

Tape No.	Range, mm.	Proportion.
T_{816}	0.045	1 part in 1,110,000
T_{817}	0.118	1 part in 420,000
T_{821}	0.297	1 part in 170,000
T_{822}	0.112	1 part in 450,000

Each of the tapes was longer at the time of the last standardization than at the first one, the average increase being 0.143 mm. or one part in 350,000. These changes are within the possible effect of the accidental and constant errors of standardization, except in the case of T_{521}. That tape shows a continuous increase from May, 1909, to October, 1913, but the maximum change in the length of this tape between any two consecutive standardizations is only 0.131 mm. (March, 1910, to March, 1912), or one part in 380,000. The maximum change between two consecutive standardizations for T_{516} is 0.088 mm., or one part in 570,000; for T_{517} it is 0.131 mm., or one part in 380,000 (the same as for T_{521}); and for T_{522} it is only 0.051 mm., or one part in 980,000.

Tape T_{522} was carried to the field by each party measuring the bases on the Texas-California arc and on the 104th meridian, but in no case was it used in the measurements. In fact, it was never unreeled in the field. Therefore any change in length of that tape has been due to other causes than those incident to the use of tapes in the field during measurements.

The data in the table on page 670 indicate a remarkable constancy in the values of the lengths of the tapes, considering the fact that three of them were used in the field in the measurement of six bases, totalling about 156 kilometres of single measures, about 52 kilometres for each tape. It may be stated also that the invar tapes are not so susceptible of injury during field work as was supposed to be the case soon after their introduction. Each of the base parties which used the tapes under discussion had only two members who were skilled in the use and treatment of tapes, the other persons in the party being unskilled men. The members of each party were cautioned to use every care in handling the tapes, but, even so, it seems remarkable that not one of the tapes has been injured.

Invar wires are used in some of the other countries with great success. The advantages of wires over tapes about equally balance the advantages of the tapes over the wires. Each type of apparatus will give results far greater in accuracy than that required. The wire is less affected by the wind. The tape is more easily reeled and unreeled than the wire. The wire may become twisted without detection, while this seldom happens with the tape. The wire seems to be more subject to kinks than

the tape. Owing to the lesser thickness of the tape, a smaller diameter may be used for its reel than for the reel of the wire.

The method of supporting the tape or wire during measurements, of applying the tension, and of marking successive lengths varies greatly. Each method has its advocates and special advantages. The method employed in the Coast and Geodetic Survey is to set stakes firmly, throughout the length of the base. At 50-metre intervals (the length of the tape) a stake four inches in cross-section is used. The intermediate supports are nails driven horizontally into stakes set just off the line. Usually only one intermediate support is used and, except in rare cases, its top is in a straight line with the tops of the two end supports. The tape lengths are transferred to copper strips nailed to the tops of the end supports, the strips being of the same thickness as the sleeves of the tape which carry the graduations. The tension is given by a spring balance attached to the stretcher.[4] A line of levels is run over the base in both directions to get the grades from which corrections to give the horizontal distance are computed. The setting of the stakes and the levelling may be done in even strong winds, while the calmest days are utilized for the measuring with the tapes.

The base party usually consists of six persons and only one needs to have had previous experience in the work. In fact, the measurement of even a primary base is so simple an operation that this work is now considered a mere incident of the triangulation and is done by the triangulation party. This plan has two decided advantages: first, the lengths of the bases will be known when the triangulation of an arc has been completed; and, second, the base work can be done at much lower cost than where a party is especially organized and outfitted for measurement of bases.

The average field cost of measuring a base by the triangulation party is about $50 per kilometre. The cost by special parties may be fifty per cent. greater than this. The cost of the measurements with base bars varied greatly, but the minimum was several times greater than that with the tapes.

It is evident from this sketch of apparatus and methods employed in base measurements that tapes and wires have replaced bars. Bars from now on will be found in museums and should have a prominent place only in histories of geodesy.

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[4] See Appendix 4, Coast and Geodetic Survey Report for 1910.

REFRACTIVE INDEX AND DENSITY.*

BY

IRENE MAUD MATHEWS.

THE relation between the refractive index of a substance and its density is a problem of no recent origin—and yet it is one of modern interest, for one form of the relation is a deduction from the electron theory of matter, of all the greater importance because of its tangibility from a practical point of view. The earliest theory was, μ being the refractive index, d the density,

$$\frac{\mu^2-1}{d} = \text{constant} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

This was supported by Newton. He remarks: "If light be swifter in bodies than *in vacuo* in the proportion of the sines which measure the refraction of the bodies, the forces of the bodies to reflect and refract light are very nearly proportional to the densities of the same bodies, excepting that unctuous and sulphurous bodies refract more than others of the same density." Newton's formula was established by Laplace on the emission theory, and, as one would expect, it has been definitely refuted by experiment. The anomalous behavior of the sulphur compounds, on the other hand, is both admitted and unexplained.

On the electron theory we have

$$\frac{\mu^2-1}{(\mu^2+2)d} = \text{constant} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The only serious rival of this is Gladstone and Dale's empirical relation,

$$\frac{\mu-1}{d} = \text{constant} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

though Magri [1] has also considered the relation

$$\frac{\mu^2-1}{(\mu^2+1)d} = \text{constant},$$

finding it somewhat incorrect.

As the density of gases and vapors can be varied so much more easily than that of solids and liquids, it is experiments on

* Communicated by Prof. James Barnes, Bryn Mawr College.

[1] *Phys. Zeit.*, 6, 1905, p. 629.

gases that form the best test of the various theories. The earliest experiments were with atmospheric air. Biot and Arago used a hollow prism, filled with air, and observed, through a telescope, the shift of a distant mark seen through the prism, as the pressure of the air was altered. As they neglect dispersion, their results are only a rough approximation and can in no way distinguish between the three relations (1), (2) and (3); however, (2) was not known till about 1880, when L. Lorenz deduced it on the elastic solid theory of light—for the quantities $(\mu^2 - 1)$, $\frac{\mu^2-1}{\mu^2+2}$ only differ from a numerical multiple of $(\mu - 1)$ by terms of the order $(\mu - 1)^2$. For ordinary air $\mu - 1 = .0003$ approximately, so that $L(\mu - 1)^2 = 9 \times 10^{-8}$.

The first to take account of dispersion was Ketteler.[2] He used a Jamin interferometer, with two equal glass tubes (40 mm. long) between the plates, and sodium, lithium, and thallium flames as his sources.

If l = length of either tube,
λ_1 = wave-length of light used in the air in the first tube,
λ_2 = wave-length of light used in the air in the second tube,
λ_0 = wave-length of light used in free space,

Then $l = n_1\lambda_1$ say
$= n_2\lambda_2$
$= \frac{n_1\lambda_0}{\mu_1} = \frac{n_2\lambda_0}{\mu_2}$ μ_1, μ_2 being the respective refractive indices.

$\therefore\ \mu_1 - \mu_2 = \frac{\lambda_0}{l}(n_1 - n_2)$

Ketteler varied the pressure of the air in one of the tubes and counted the number of interference bands that passed,—*i.e.*, $(n_1 - n_2)$, assuming the tubes equal, and found that the relation

$$n_1 - n_2 \propto (p_1 - p_2)$$

always held for all pressures, p, used—or with the above

$$\frac{\mu_1 - \mu_2}{p_1 - p_2} = \text{constant}$$

or $$\frac{\mu_1 - \mu_2}{d_1 - d_2} = \text{constant, assuming Boyle's law.}$$

If one of the tubes is evacuated, this becomes

$$\frac{\mu - 1}{d} = \text{constant.}$$

[2] *Pogg. Ann.*, 124, 1865, p. 390.

Ketteler points out that the difference between (1) and (3) is within his experimental error. Besides air, he used carbon dioxide, hydrogen, cyanogen, and sulphur dioxide, finding the same result to be true of each gas.

Mascart [3] performed more accurate experiments, using sodium light and Fizeau's biplanes to observe Talbot bands. First he varied the pressure of the air in one of his tubes, keeping the temperature constant. Mascart found that the number of bands passing as the pressure changed from p_1 to p_2 was proportional to

$$(p_2-p_1)\left(1+b\,\frac{p_1+p_2}{2}\right)$$

or $\mu_2-\mu_1 = a\,(p_2-p_1)\left(1+b\,\frac{p_1+p_2}{2}\right)$ a, b, being constants.

Now, according to Regnault, the relation between density and pressure, up to 8 atmospheres, neglecting p^3, is

$$d = Ap(1+Bp)$$

or $$d_2-d_1 = A(p_2-p_1)[1+B(p_1+p_2)]$$

where A, B, are constants, d_1, p_1; d_2, p_2, being corresponding values of d, p.

Up to 6 metres of mercury, Mascart found $\frac{b}{2} = B$ when the temperature was constant. Thus his relation for refractive index in terms of pressure, combined with Regnault's results for density in terms of pressure up to p^2 term, proves the truth of relation (3) in opposition to (1). He checks his results by using four cadmium lines as sources. On the other hand, varying the temperature, he found that the relation (3) was not accurate for

$$\mu-1 = (\mu_0-1)(1+\beta t)$$

where β is *not* the coefficient of expansion of air. There is not, however, sufficient evidence that Mascart has accurately performed all the necessary corrections for the effects of change of temperature on the dimensions of his apparatus. Besides air, he experimented on nine other gases.

Von Lang [4] next takes up the question, discussing Fizeau's recalculation of Biot and Arago's results, as well as Mascart's results. He used a spectrometer whose prism is enclosed in a

[3] *C. R.*, 78, 1874, pp. 617 and 679; 86, 1878, p. 321.

[4] *Pogg. Ann.*, 153, 1874, p. 448.

vessel heated by hot water, and calculates the refractive index of air for every 5° from 0° to 100° C., taking precautions against the variation in the dimensions of his apparatus due to change of temperature.

Von Lang finds for sodium light

$$\mu = \mu_0 - 0.000000905t$$

$$\text{or} \quad \mu - 1 = 0.0002923(1 - 0.00310t)$$

Mascart gets

$$\mu - 1 = 0.0002923(1 - 0.00383t)$$

Von Lang misquotes his result.

But the coefficient of expansion of air is .00367; thus neither of the results confirms formula (3), but their discrepancies are in different directions.

Shortly after this L. Lorenz [5] did some very striking work, both theoretical and practical. To obtain the relation between the refractive index of a substance and the density for a constant wave-length, he assumes that the body is isotropic and consists of spherical molecules between which the light is propagated with the same velocity as in free space.

His differential equations are

$$\text{curl. curl } V = \frac{1}{\omega^2} \frac{\partial^2 V}{\partial t^2}$$

V being a vector, ω a rapidly varying function of the coördinates (x, y, z) in the body, and becoming a constant in free space. He treats the case of a plane wave of infinite wave-length, and concludes

$$\frac{\mu^2 - 1}{\mu + 2} v = \frac{\mu_i^2 - 1}{\mu_i^2 + 2} v_i$$

where v is the volume of unit mass of the substance, v_i the specific volume of the molecule, μ_i the refractive index for light in the interior of the molecule, assumed constant for the molecule. He has, therefore, established formula (2) for all changes of density, whether accompanied by a change of temperature or not—provided the internal condition of the molecule is unchanged. Lorenz is careful to state that the truth of his

[5] *Wied. Ann.*, 11, 1880, p. 70.

hypotheses can only be judged by the experimental determination of $\frac{\mu^2-1}{(\mu^2+2)d}$ for different states of the same substance.

His experiments were conducted with the Jamin interferometer. He finds that for sodium and lithium light the refractive index of water between 0° and 30° C. obeys either of the laws (2) or (3), which are indistinguishable. But his crucial experiments were those by which he measures the refractive indices of seven different fluids in the liquid and gaseous states, and finds the law (2) to be considerably superior to (3), the greatest deviation being 5 per cent. Finally, he considers the modification of the law (2) for finding the refractive index of a compound from those of its constituents. This is interesting in the light of recent experimental work.

Shortly after L. Lorenz had deduced the law (2), H. A. Lorentz obtained it quite independently on the electromagnetic theory of light: he gives a modification of his original proof in his "Theory of Electrons."

The superiority of Lorenz's formula to formula (3) for substances in the liquid and vapor states was also demonstrated by Bleekrode [6] for eleven different fluids.

Quincke [7] experimented with fluids under hydrostatic pressure, measuring directly their compressibility and counting the number of interference bands which pass under the same circumstances—thus obtaining optically a measure of the compressibility. His conclusion is that (3) agrees with experiment, but that (1) and (2) do not.

Benoit [8] used Fizeau's apparatus for measuring the expansion coefficient by means of Newton's rings, and showed the accuracy of the law (3). L. Lorenz's result was also confirmatory, for he obtained the reduction factor $(1-0.00368t)$, while Mascart's and Von Lang's results were negative.

Chappuis and Rivière [9] worked with carbon dioxide and cyanogen at 21 ° C. for different pressures up to 19 atmospheres. They concluded that as far as the p^2 term the laws (2) and (3) hold equally.

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[6] *Proc. Roy. Soc.*, 37, p. 339.
[7] *Phil. Mag.*, 5, 17, 1884, p. 65.
[8] Mem. du Bureau International des Poids et Mesures, 6, 1888.
[9] *C. R.*, 103, p. 37.

Unlike all previous as well as all subsequent writers, Sutherland [10] claims that the law (3) is not merely empirical, but has a theoretical foundation. He gives a proof of it which, apparently, has not convinced many people. Moreover, he attacks L. Lorenz's mathematics on what would seem to be unjustifiable grounds. For, while considering a very large wave-length so as to eliminate dispersion, Lorenz states that the refraction of the molecule is *not* small.[11] Thus the function ω, which represents the velocity of light in free space, becomes within the body a very rapidly varying function of the coördinates (x, y, z). Lorenz then *does* provide for a change of wave-length in passing from ether into matter; his only stipulation is that this change is the same for all molecules of the body, and that in the interstices the wave-length is the same as in free space.

A new experimental method was introduced by Kayser and Runge.[12] They used a Rowland concave grating, and placed a hollow metal prism filled with air between the grating and the photographic plate, so that one-half only of the light passed through the prism. They therefore obtained simultaneously two spectra: in one, half the line showed in its usual position; in the other, the remaining half was shifted as soon as the density of the air in the prism was changed. Their experiments are extremely careful and cover a range of temperature from 10° to 17° C. and an excess of pressure of the air in the prism of 8 m. mercury. Their conclusion, both from their own and from previous researches, is that the law (3) is rigorously true.

After the Rowland grating, the next instrument used was the Michelson interferometer. Gale [13] let the two beams pass through tubes, one of which was almost evacuated. The pressure of the air in the other was gradually reduced and the number of interference bands passing was counted. He concluded that the laws (2) and (3) are indistinguishable for the pressures used, and that any departure from either must be within 1 per cent.

In view of the anomalous results as to the truth of the law (3) for different temperatures, George W. Walker [14] repeated

[10] *Phil. Mag.*, 5, 27, 1889, p. 141.
[11] *Wied. Ann.*, 11, 1880, p. 71.
[12] *Wied. Ann.*, 50, 1893, p. 293.
[13] *Phys. Review*, 14, 1902, p. 1.
[14] *Phil. Trans. A.*, 201, 1903, p. 435.

the experiments with the Jamin interferometer. He obtained the ratio

$$\frac{\text{number of bands passing}}{\text{change of pressure}}$$

for about six different pressures and constant temperature; and then repeated for another temperature. This was done for 16 temperatures, varying from 10° C. to 100° C. He corrected for the change in length of his tubes, which were of brass, and about 100 c.m. long, taking as the coefficient of expansion of brass 0.000019. He then compared the ratios:

$$\frac{\text{Bands}}{\text{pressure}}(1+.00355t);\quad \frac{\text{Bands}}{\text{pressure}}(1+.00360)t;\quad \frac{\text{Bands}}{\text{pressure}}(1+.00365t),$$

deciding in favor of the middle one, giving a coefficient of expansion .00360 ± .00003.

A large enough difference of pressure to distinguish between (2) and (3) was at last obtained by Magri.[15] He focussed the light from a mercury vacuum arc on the plates of a Jamin interferometer, and, varying the pressure up to about 200 atmospheres, he counted the number of bands passing. The gas was compressed in a large vessel, which was connected to an instrument, for measuring the density, as well as to the interferometer tube. Magri rejects relation (1) and finds (3) is little better, preferring $\frac{\mu^2-1}{(\mu^2+1)d}$ = constant to either. H. A. Lorentz points out in his "Theory of Electrons" (English edition, p. 146) that Magri's results agree well with (2).

Let us consider what difference we should expect between (2) and (3), as μ varies. Putting $\mu = 1+\epsilon$ where ϵ is small

$$\begin{aligned}
\frac{\mu^2-1}{\mu^2+2} &= \frac{(1+\epsilon)^2-1}{(1+\epsilon)^2+2} \\
&= \frac{2\epsilon+\epsilon^2}{3}\left(1+\frac{2\epsilon+\epsilon^2}{3}\right)^{-1} \\
&= \frac{2}{3}\epsilon\left(1+\frac{\epsilon}{2}\right)\left[1-\frac{2\epsilon+\epsilon^2}{3}+\frac{(2\epsilon+\epsilon^2)^2}{9}\right] \text{ neglecting } \epsilon^4, \text{ etc.} \\
&= \frac{2}{3}\epsilon\left(1+\frac{\epsilon}{2}\right)\left(1-\frac{2}{3}\epsilon+\frac{\epsilon^2}{9}\right) \\
&= \frac{2}{3}\epsilon\left(1-\frac{\epsilon}{6}-\frac{2}{9}\epsilon^2\right)
\end{aligned}$$

[15] *Phys. Zeit.*, 6, 1905, p. 629.

Thus neglecting ϵ^2, we see that (2) and (3) are indistinguishable. This holds at atmospheric pressure, and in fact, up to about eight atmospheres. If, for example, $\mu = 1.0003 = 1 + \epsilon$, we have

$$\frac{\mu^2-1}{\mu^2+2} = \frac{2}{3}(\mu-1)(1-.00005)$$

$$= \frac{2}{3}(\mu-1) \text{ to within 1 in 10,000.}$$

Some very interesting work has been done by C. Cuthbertson [16] on the refractive indices of the elements. He used the Jamin interferometer, placed a weighed quantity of the substance to be examined in one of the tubes, and evacuated and sealed off both tubes. He then heated the tubes in an electric furnace, counting the bands as they passed, until all the substance was vaporized. Later he had his furnace in two parts so that the vapor could be quickly condensed, by pouring cold water over the exposed centre of the tube, and heated up again in a few minutes; the counting process, therefore, became a question of minutes instead of hours. His earlier experiments aimed at a 1 per cent. accuracy, and he specially noticed a spurious starting effect, explained as due to unequal heating. It may be some such effect as this that has produced the contradictions in the optical coefficient of expansion. He calculates the value of μ for the density at which the number of atoms of the element per unit volume equals the number of hydrogen atoms in unit volume at 0° C. and 760 mm. pressure. The density of the vapor in the experiment is found by dividing the volume of the tube by the weight of the element volatilized. Cuthbertson calculates the value of the refractive index of various compounds, knowing those of the constituents, and compares the result with experiment. In some groups there is a good agreement; but in the case of the sulphur compounds we have notable exceptions.

Thus for sulphur dioxide we should have $(\mu - 1)10^6 = 825$. But experiment gives 661.

He finds that the values of $(\mu - 1)$ for the elements of the nitrogen oxygen halogen and argon groups are to one another in certain simple numerical ratios. It should be noted that as μ is of the order 1.002, $\frac{\epsilon}{6} = .0003$. Hence, as shown above to

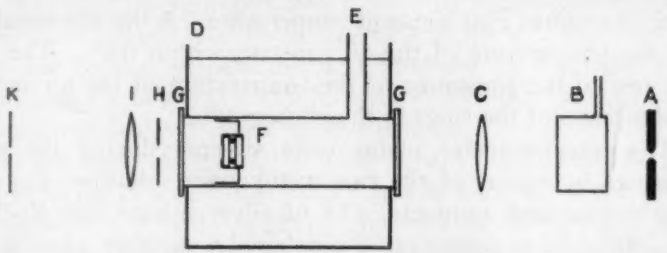
[16] *Phil. Trans. A.*, 204, 1905, p. 323; 207, 1907, p. 135. *Proc. Roy. Soc.*, 76, 79, 80, 81, 83, 84.

within an accuracy of 1 in 1000, $\frac{\mu^2-1}{\mu^2+2}$ is identical with $\frac{2}{3}(\mu-1)$, and the above ratios are probably those of the number of dispersion electrons in the atom; also we have the experimental verification of the Lorenz formula for the refraction index of a compound.

The sum total, then, of the evidence is this: The choice lies between (2) and (3)—and for low densities they are indistinguishable. Formula (2) has unquestionably the advantage on theoretical grounds. As regards experiment, it is supported (*a*) by Magri's experiments at high pressures, (*b*) by the experiments of Lorenz and Bleekrode on substances in the liquid and vapor states, and (*c*) Cuthbertson's experiments on compounds on the whole support the relation deduced from (2).

On the other hand, there is a remnant of doubt as to whether

FIG. 1.



either (2) or (3) holds when the temperature varies. The experiments of Lorenz, Benoit, Kayser, and Runge support them; those of Mascart, Von Lang, and Walker do not. Dr. Barnes suggested to the writer that she should make use of the instrument least affected by temperature variations,—namely, the Fabry and Perot interferometer,—and measure the refractive index of air, in the first place, and then of oxygen, for different pressures at the same temperature and then at different temperatures. Another important advantage of this interferometer is that it is preëminently adapted for work in the ultra-violet region, while for all wave-lengths, since the calculations are made from photographic measurements, it eliminates the error due to a miscount of the bands passing. These experiments, however, were only just started.

The light from an arc *A*, Fig. 1, of copper zinc alloy after

passing through a water bath *B*—which absorbed the heat rays—was focussed by a lens *C* on the plates of the Fabry and Perot interferometer, which was in a hollow chamber *F* of a metal vessel *D*. The central rays, after traversing the interferometer and the aperture in the screen *H*, were focussed by the lens *I* on the slit *K* of a Hilger constant deviation spectroscope, giving an image consisting of the usual spectral lines crossed by circular black rings, part of which were only visible (except for the central small dark circle, which was entirely visible if the centre were black). The vessel *D* was cubical in shape, with a cylindrical tunnel *F* through the centre. This tunnel *F* was completely cut off from the rest of the vessel, a pipe *E* leading out of it; when its ends were covered with glass plates *G*, sealed on with wax, it formed an air-tight chamber, and the pipe *E* connected it with the column of mercury, which measured the pressure, as well as with the pump. The vessel *D* was filled with oil to maintain the air within the tunnel *F* at constant temperature. A thermo-regulator kept the temperature of the oil constant within 0.1°. The ultimate test of the constancy of the temperature of the air in *F* is the sharpness of the rings in the photograph.

The interferometer plates were silvered during the early exposures by means of the two well-known solutions—(*a*), of silver nitrate and ammonia, (*b*) of silver nitrate and Rochelle salt. After the exposure series numbered 6, another solution was used, the silver being deposited by the agency of formaldehyde. After being silvered, the plates were pressed on three steel balls held in a ring (the balls projecting beyond the ring), the pressure being exerted by three pressure screws. An area rather less than a square centimetre of the plates was exposed. The plates were placed with extreme care in the chamber *F*, the final adjustments made, and the glass plates *G* sealed on. Another adjustment requiring great care was the position of the lens *I*, which must be placed so that the rings are sharply focussed on the slit of the spectroscope.

Preliminary experiments determined carefully the magnification of the spectroscope, the focal length of the lens *I*, and the distance between the plates. The magnification of the spectroscope was found by placing a small piece of ruled glass across the slit and photographing the rulings, and measuring carefully

the rulings both on the glass and the photographic plate. This gives the ratio

$$\frac{\text{diameter of ring on slit}}{\text{diameter of ring on photographic plate}} = k.$$

The focal length f of the lens I was found by placing it on the revolving table of a spectroscope, of which the collimator was fixed, adjusted for parallel rays, rotating it through a small angle, and photographing the image of the slit. Then

$$f = \frac{d}{\tan\theta}$$

when d is the linear shift of the image for a rotation θ. This method gave very concordant results. To determine the optical distance e between the plates, the diameters of the steel balls were first measured by a micrometer screw, and the mean taken. Then, after the adjustment of the apparatus, an exposure was made, and the order of the centre determined by Rayleigh's method.[17] After much useless labor with Kayser and Runge's wave-lengths, corrected to the temperature and pressure of the experiment, Fabry and Perot's wave-lengths were tried: they gave the number required without much further trouble.

In the early stages of the work it was hoped that the labor of finding the order of the centre might be avoided by the following device. If θ is the angle of incidence of the light, of wave-length λ_0 in free ether, θ_1, θ_2 refer to successive rings when the vessel is evacuated, θ_1 θ_2' to any two successive rings when there is air between the plates, then, n_1 being a whole number, we have

$$\frac{2e}{\lambda_0}\cos\theta_1 = n_1$$

$$\frac{2e}{\lambda_0}\cos\theta_2 = n_1 - 1$$

$$\therefore \quad \frac{e}{\lambda_0}\left(\theta_2^2 - \theta_1^2\right) = 1, \quad \text{neglecting } \theta^4$$

$$\text{So} \quad \frac{e}{\lambda}\left(\theta_2'^2 - \theta_1'^2\right) = 1$$

$$\therefore \quad \frac{\lambda_0}{\lambda} = \frac{\theta_2^2 - \theta_1^2}{\theta_2'^2 - \theta_1'^2}$$

[17] *Phil. Mag.*, 6-11, 1906, p. 685; 15, 1908, p. 548.

and $\mu = \dfrac{d_2^2 - d_1^2}{d_2'^2 - d_1'^2}$ when d is the diameter of the ring on the photographic plate $\theta = \dfrac{kd}{2f}$.

It was easily seen on trial that the diameters of the rings cannot be measured with sufficient accuracy for the formula to be a practical one.

The calculation was as follows:

P_0 is the order of the ring of diameter d_0 *in vacuo*
P is the order of the ring of diameter d *in air*

Then $\begin{cases} \dfrac{2e\cos\theta_0}{\lambda_0} = P_0 \\ \dfrac{2e\cos\theta}{\lambda} = P \equiv n + P_0 \text{ where } n \text{ is a small integer} \end{cases}$

give $\mu = \dfrac{P}{P_0}\left[1 + \dfrac{k^2}{8f^2}(d^2 - d_0^2)\right]$, neglecting θ^4, etc.

$$\mu = 1 + \frac{n}{P_0} + \frac{k^2(d^2 - d_0^2)}{8f^2} + \frac{n}{P_0}\frac{k^2(d^2 - d_0^2)}{8f^2} \quad \ldots\ldots\ldots\ldots (A)$$

for the values concerned it was found that the last term was negligible.

Only one of the half dozen spectral lines has been worked up: $\lambda = 5105.6$ Å. U. for two independent sets of plates.

Plate No.	Pressure mm. Hg.	μ
Cu. 6— 1	26	1.0000092
2	83	1.0000300
3	178	1.0000652
4	274	1.0000996
10	588	1.0002124
11	659	1.0002330
12	738	1.0002576
13	753	1.0002630
Cu. 7— 6	38	1.0000155
7	112	1.0000381
8	201	1.0000697
9	280	1.0000991
10	359	1.0001283
11	436	1.0001575

12	439	1.0001588
13	518	1.0001878
14	600	1.0002137
15	675	1.0002511
16	749.5	1.0002609
17	756	1.0002659

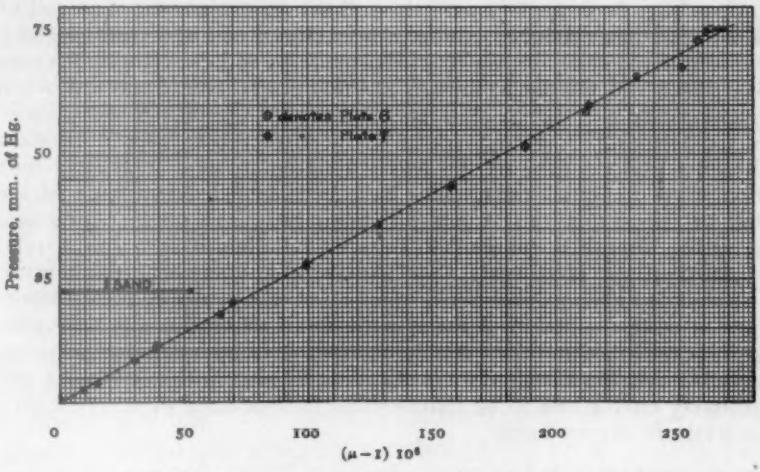
Temp. 25.9° C.

Exposures were made at lower pressures, but these were used to calculate d_0. Equation (A) shows that, as $(\mu - 1)$ for small pressures p is proportional to p, we must have

$$\frac{\Delta d^2}{\Delta p} = \text{constant for the same ring.}$$

The results are represented graphically in Fig. 2, showing

FIG. 2.



Refractive index and pressure (λ=5105 Å.U.) for air, 25.9° C.

that they are probably accurate to within $\frac{1}{20}$ of a band—which is of higher accuracy than that given by most other interference methods. The supreme advantage of the method is that the only temperature error is the alteration of the distance e ($2e = .94960$ cm.), which at once becomes obvious by the haziness of the rings, whereas for a corresponding variation of temperature twenty or thirty bands might pass in the case of the Jamin instrument and

tubes 100 c.m. long. This method, then, could detect the difference between the laws (2) and (3) at pressures of about seven or eight atmospheres, and it is a most suitable method for different temperatures.

In conclusion, I should like to thank Dr. Barnes for his kind assistance and encouragement in the course of these experiments at Bryn Mawr College in 1910–11, as well as for the drawings of the apparatus used. Subsequently my thanks are due to the librarians of Sheffield and of Manchester Universities for their kind permission to use the libraries of the Universities.

CITY AND COUNTY SCHOOL, CHESTER, ENGLAND, December, 1913.

Practical Applications of the Gyroscope. J. AIREY (*Amer. Mach.*, xl, No. 15, 635.)—During the last decade, practically, gyroscopes have been applied with the following results: (*a*) The roll of a ship has been reduced, and can be reduced to any extent desired, even to zero. (*b*) A ship has been made to roll even though waves are absent, to enable a ship to shake herself free from ice when opening a track. (*c*) A ship has been made to pitch for the purpose of ice-breaking. (*d*) A torpedo has been forced to keep a constant direction independent of the waves tending to send it askew. (*e*) Platforms for quick-firing guns have been kept level in spite of the roll of the ship. (*f*) A one-rail train has been made a practical venture; though it remains to be seen whether it is a commercial venture on any large scale. (*g*) An aëroplane has been made automatically to keep a level deck. (*h*) Last, but probably most important, a compass has been made which will determine the true geographical North and thus enable navigators to be independent of the variable and troublesome magnetic North; also in the future, it will probably enable one to be independent of fine days or starry nights in accurate survey work.

Coating Iron with Aluminum ANON. (*Metal Ind.*, xii, No. 2, 77.)—A process invented by S. Uyeno, of Tokyo, coats iron with aluminum by dipping it in a bath of the molten metal after it has first been galvanized. The aluminum bath is held at the temperature of 600° to 700° C. The temporary zinc or tin surface comes away in the first dipping, but to get the best results the article to be coated is treated two or three times. The surface of the article is brushed with a steel brush during immersion. It is claimed that the aluminum coating has extraordinarily good adhesion, so that it will not peel off, and even cannot be stripped off by mechanical means. It does not tarnish under the influence of air, heat or water.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

IODINE NUMBER OF LINSEED AND PETROLEUM OILS.[1]

By W. H. Smith and J. B. Tuttle.

THE Iodine Number of linseed and petroleum oils was determined according to the Hanus method. Each of the three factors, weight of sample, time of absorption, and amount of Hanus solution, was studied for a series of burnt linseed oils and petroleum oils. The results produced by variation of one of the factors, the others remaining constant, are reproduced graphically. Variations of weight of the raw linseed oil show that a constant volume is obtained for weights of the oil up to 0.25 gram. Beyond this value, the iodine number decreases with increasing weight. For burnt linseed oils, the range of weight over which the iodine value is constant decreases with increased burning of the oil. Petroleum oils, on the contrary, approach a constant value when 0.6 gram or more of the sample is taken. Varying the time of absorption from five to sixty minutes shows that the reaction approaches a maximum in about ten minutes. Thereafter, absorption is slow, and a few minutes one way or another have little effect on the value obtained. When the amount of Hanus solution is varied from 20 to 75 c.c. the results indicate that the oil with the highest iodine number does not require the greatest excess of iodine to reach maximum absorption value. The effect of temperature on the value obtained is more marked for burnt linseed oils than for boiled or raw oils. The results as a whole indicate that concordance is obtained only when a prescribed procedure is followed with exactness. To obtain comparable results, a standard procedure should be followed in which the limits are strictly defined. This is particularly true of burnt linseed oils.

* Communicated by the Bureau.

[1] Technologic paper of the Bureau of Standards, No. 37.

FLAME STANDARDS IN PHOTOMETRY.[2]

By E. B. Rosa and E. C. Crittenden.

ALTHOUGH an agreement has been reached regarding the relative values of the units of light in use in different countries, no one primary photometric standard has been generally adopted by the various governments. In Germany preference is given to the Hefner lamp, in England to the pentane lamp, and in France to the Carcel lamp. Each of these serves in its own country both as the primary standard and as a working standard, but for the photometry of electric lamps and generally in accurate photometric work standardized electric incandescent lamps are used in all countries. In America a group of such lamps kept at the Bureau of Standards is considered as a provisional primary standard, serving to maintain the unit until a better primary standard shall have been devised. It is believed that the unit which has been agreed upon can be so maintained with an accuracy considerably above that with which it can be reproduced by reference to any of the so-called reproducible standards at present in use. In other words, the incandescent lamps have really been employed as primary standards, and the flame standards, which logically should play the part of primary standards, have been relegated to a subordinate position.

There is, however, a possibility of an appreciable drift in the value of the unit if there is no photometric standard accurately reproducible from its specifications which is capable of serving as a reliable check upon the electric standards. It has therefore appeared worth while to make a study of the best types of flame lamps to see how closely they would reproduce in the Bureau laboratory the values adopted by international agreement and also to find whether their reliability as primary standards could be increased by any changes in construction or in operation.

The present paper discusses at length the effect of atmospheric conditions on the intensity of flames, and gives tables and curves showing the performance of typical lamps. These data are largely taken from an earlier paper (Trans. Illuminating Engineering Society, 5, p. 753, 1910).

The Carcel lamp is by far the least reliable of the three types, and cannot be considered as a competitor for general acceptance.

[2] Abstract of paper to be published in the Bulletin of the Bureau.

The Hefner and the pentane lamp as made at present divide honors; the latter is markedly superior as a practical standard, but individual pentane lamps do not agree, and until lamps can be independently made which shall give the same value the type can hardly be said to be reproducible. The Hefner lamp is so simple in construction that reproduction of lamps is relatively easy. Lamps now made show small differences due to slight departures from mean dimensions, but these differences can be made negligible by more careful construction. Great difficulty is experienced, however, in making accurate comparisons of working standards against Hefner lamps because of the very low intensity (0.9 candle) and the red color of the flame.

It is believed to be possible to apply the principle of the present pentane lamp in specially made, accurately specified lamps with interchangeable parts, and thus to obtain a closer agreement between lamps. Then by operating the lamps under definite conditions one should be able to obtain sufficient precision with either the Hefner or the pentane lamp to give a valuable check on the electric standards now in use.

Disappearance of two Pacific Islands. Anon. (*Sci. Amer.*, cix, No. 26, 487.)—Press reports state that Falcon and Hope Islands of the Tonga or Friendly group, in the South Pacific, have sunk in the sea, carrying with them several hundred natives and a few white men. Both were volcanic islands. Falcon Island was first seen as a breaking reef from H. M. S. "Falcon" in 1865; in 1877 smoke was seen issuing from the sea at this place; and finally, in 1885, a full grown island appeared, consisting of loose volcanic ashes. A considerable part of it was subsequently washed away by the action of the sea. It is assumed that the "Hope Island" of the newspaper report is Good Hope Island or Niuafou, which has been the site of numerous volcanic outbreaks, entailing much loss of life and property. The Tonga Islands constitute a native kingdom under British protection.

French Mail Line by Air across the Sahara. Anon. (*Sci. Amer.*, cx, No. 3, 61.)—The National Aërial League has completed plans for the flight of a flotilla of aëroplanes across the Sahara. They will start from Oran, Algeria, and the final landing will be made at Timbuktu, French Soudan, a distance of 1400 miles. Pyramids of stones will be placed at intervals to mark the route. If the experiment proves successful the establishment of a regular air mail service will be considered.

Production of Luminescence by Kathode and Canal Rays at Liquid-air Temperature. E. OHLON. (*Ark. för Mat. Astron. och Physik.*, viii, 22.1.)—A large number of minerals and metallic salts were examined with regard to their properties of emitting luminescence under the action of kathode and canal rays. The observations with minerals were of a preliminary character only and revealed the fact that the intensity of the luminescence produced by these agencies was much greater at low than at ordinary temperatures. Therefore the observations with the metallic salts were made at the temperature of liquid air. With the salts of the more electropositive metals, viz.: Li, Na, K, Ca, Ba, Sr, and Mg, two types of luminescence are to be observed. When the salts are first subjected to the rays a bluish luminosity is seen which diminishes in intensity, in some cases rapidly, giving place to a second luminescence which varies in color according to the salt. With the salts of Zn, Cd, Pb, Hg, Fe, Cu and Mn, luminescence of the second type only is to be observed. After comparing these results with those of Goldstein and others, it is concluded that the first type of luminescence, which is similar for different substances, is caused by the escape of electrons, since it occurs with salts of the photoelectric metals; the second type is due to the escape of the metal atoms which have previously lost their valency electrons, for in some instances when canal rays are the exciting agency, the luminosity gives line spectra characteristic of the metal. However, the spectra generally consist of bands. The experimental results are given in tabular form and include observations on the phosphorescence and thermoluminescence of the substances.

Instability of Electric Circuits. C. P. STEINMETZ. (*Amer. Inst. Elect. Engin. Proc.*, xxxiii, 13.)—This gives the theory of the stability and instability of electric circuits. The types of instability are classed under three heads. There are first the transient disturbances which arise, caused by changed circuit conditions, making a readjustment of the stored energy necessary. Secondly there is unstable electrical equilibrium, where the effect of the cause increases the cause. This is illustrated by the electric arc working at constant potential and by an induction motor working on certain loads and between certain speed-ranges. In the third type there is permanent instability due to a combination of circuit constants which cannot coexist simultaneously. This is illustrated by an arc to earth on a transmission line, by the hunting of rotary converters and the phenomena of continuous and cumulative oscillations. It is proved that such phenomena require an energy supply, due to the lag of the effect behind the cause, as in a hysteresis cycle, and often involve a transformation of the frequency. As a general illustration of this type of instability the phase-swinging of synchronous machines is discussed, the mechanism of the transfer of the oscillating energy from the power supply being pointed out.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, May 20, 1914.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 20, 1914.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership, 11.

The chairman announced that the first business of the meeting would be the presentation of Elliott Cresson Medals to the distinguished scientists who had recently been recommended for this recognition by the Committee on Science and the Arts, and recognized Dr. Harry F. Keller, who then introduced Dr. Edgar Fahs Smith, of Philadelphia, Pa., and Dr. Orville Wright, of Dayton, Ohio.

The chairman presented the medal and diploma to each of these gentlemen.

Mr. Louis E. Levy was then recognized and described briefly the work of Dr. Carl Paul Gottfried Linde, of Munich, Germany, in the field of low temperature production and commercial refrigeration, and the researches of Dr. Josef Maria Eder, of Vienna, Austria, in the science of photochemistry, the foreign medalists who were unable to be present and to whom the medals would be forwarded.

Addresses were then made by the recipients of the medals, as follows:

"Scientists from the Keystone State," by Dr. Edgar Fahs Smith.

"Stability of Aeroplanes," by Dr. Orville Wright.

After a vote of thanks to the speakers the meeting adjourned.

R. B. OWENS,
Secretary.

(A full account of the meeting will appear in the July number.)

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, May 6, 1914.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 6, 1914.

MR. GEORGE R. HENDERSON *in the Chair.*

The following report was presented for final action:

No. 2585.—E. B. Ridgway's Steam Hydraulic Elevator. Certificate of Merit. Adopted.

The following reports were presented for first reading:

No. 2588.—John V. Rice's Gasoline Rock Drills. Referred back.

No. 2593.—A. Atwater Kent's Ignition System.

R. B. OWENS,
Secretary.

SECTIONS.

Electrical Section.—A meeting of the section was held in the Hall of the Institute on Thursday evening, April 23, 1914, at 8 o'clock.

Mr. W. C. L. Eglin occupied the chair.

The minutes of the previous meeting were approved as published.

The chairman introduced Dr. A. E. Kennelly, Professor of Electrical Engineering, Harvard University, Cambridge, Mass., who delivered a lecture entitled "Recent Developments in Hyperbolic Functions, as Applied to Electrical Engineering." In this lecture Dr. Kennelly outlined the fundamental principles of hyperbolic trigonometry, by the use of which the properties of long alternating current lines are so greatly simplified. He described the advances made in the last two years in the applications of this branch of mathematics to the solution of electrical engineering problems. With the aid of lantern slides, he illustrated charts and tables of functions adapted to such application.

After a brief discussion, the thanks of the meeting were extended to the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Mechanical and Engineering Section.—A joint meeting of the section and of the American Society of Mechanical Engineers was held in the Hall of the Institute on Thursday evening, April 30, 1914, at eight o'clock.

Mr. G. R. Henderson, President, occupied the chair.

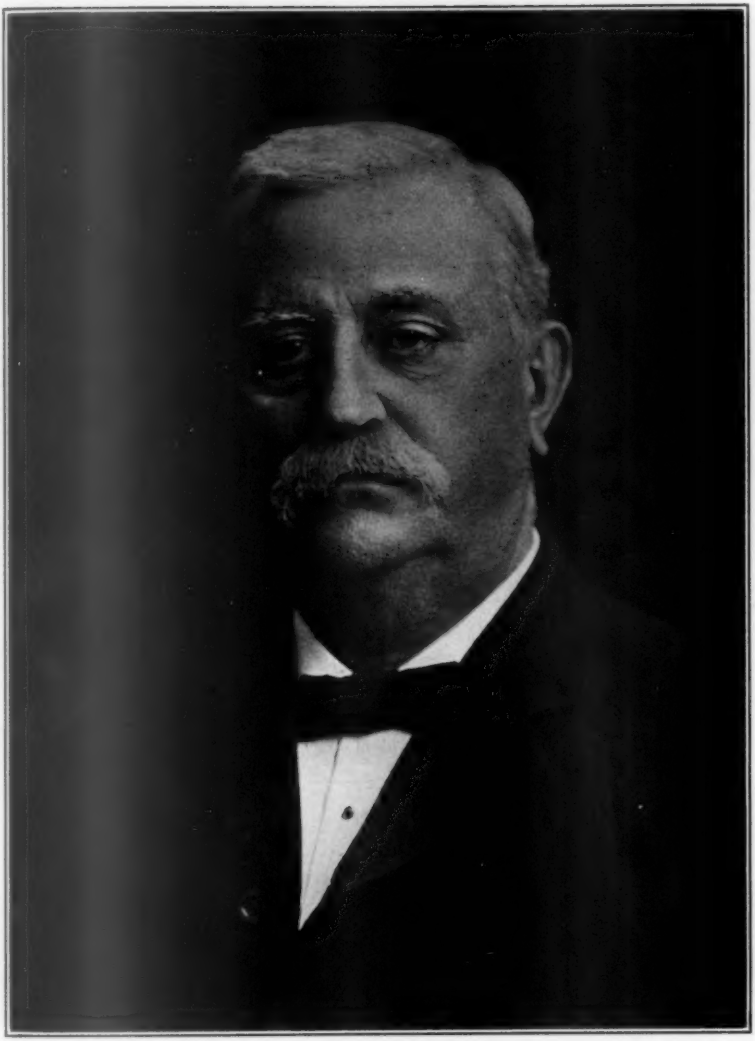
The minutes of the previous meeting were approved as published.

The chairman introduced Mr. C. D. Young, Engineer of Tests, Pennsylvania Railroad Company, Altoona, Pa., who presented a paper entitled "Locomotive Superheaters and Their Performance." The paper treated of the development of the superheater as applied to early locomotives and of its application to modern locomotives. The results obtained from exhaustive experiments at the Pennsylvania Railroad Company's Testing Plant at Altoona to determine the comparative economy of superheated and saturated steam were given. It was also indicated how these results were confirmed by actual operation on the road. The paper was well illustrated with lantern slides.

Several members present participated in the discussion, after which the thanks of the meeting were extended to the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.



Alfred Noble

U of M

MEMBERSHIP NOTES.

Elections to Membership.

(*Stated Meeting, Board of Managers, May 13, 1914.*)

RESIDENT.

MR. JOHN ASHHURST, The Free Library of Philadelphia, 13th and Locust Streets, Philadelphia.

MR. THEODORE W. CRAMP, 1411 Chestnut Street, Philadelphia.

MR. J. HERON CROSMAN, JR., The Bell Telephone Company of Philadelphia, 13th and Arch Streets, Philadelphia.

MR. GEORGE W. ELKINS, Land Title Building, Philadelphia.

MR. THOMAS FISHER, 1100 Commercial Trust Building, Philadelphia.

MR. RODMAN E. GRISCOM, 231 Land Title Building, Philadelphia.

MR. PERCY C. MADEIRA, North American Building, Philadelphia.

MR. T. E. MITTEN, 1216 Bellevue Stratford Hotel, Philadelphia.

MR. J. EDWARD PATTERSON, Secretary of Arthur H. Thomas Company, 230 South Seventh Street, Philadelphia.

MR. RICHARD P. C. SANDERSON, 107 Swarthmore Avenue, Ridley Park, Pennsylvania.

NON-RESIDENT.

MR. W. F. THORNTON, 1315 Waucoma Street, Birmingham, Alabama.

Changes of Address.

MR. LEO D. FIRMAN, 5903 Carpenter Street, Philadelphia.

DR. EDWARD P. HYDE, Nela Park, Cleveland, Ohio.

MR. J. L. KILPATRICK, Aberdale Road, Bala, Pennsylvania.

MR. TINIUS OLSEN, Hotel Stenton, Broad and Spruce Streets, Philadelphia.

MR. ISHAM RANDOLPH, 1827 Continental and Commercial National Bank Building, Chicago, Illinois.

MR. S. N. SMITH, Montgomeryville, Pennsylvania.

MR. ORIN C. STOUT, 201 Wyandotte Building, Columbus, Ohio.

NECROLOGY.

Dr. Alfred Noble was born at Livonia, Michigan, in 1844 and was graduated from the University of Michigan in 1870. After his graduation he was for some months engaged on harbor surveys on Lakes Michigan and Huron and was then placed in charge of the improvement of the St. Mary's Falls Canal, a position which he held for twelve years. In 1882 he resigned from the government service and after serving some months as Engineer of Construction of the Red River Bridge at Shreveport, La., he was appointed General Assistant Engineer of the Northern Pacific R. R., in which position he continued for three years. From 1886 to 1894 he had special charge of

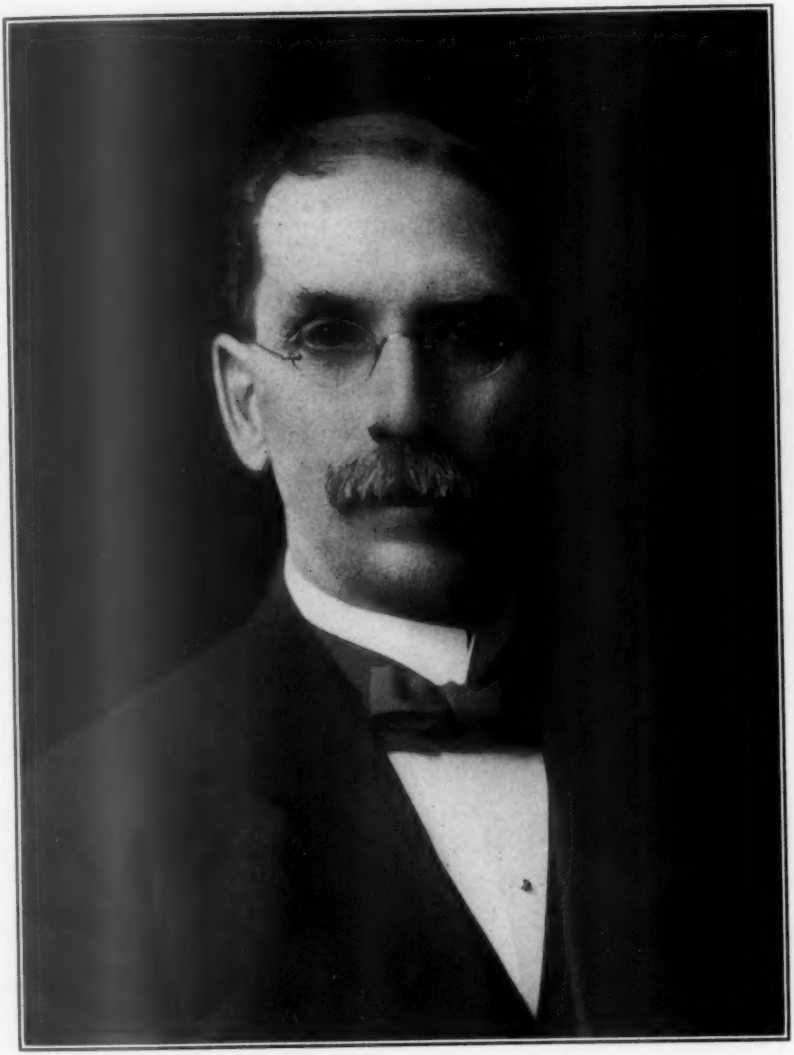
the construction of several important bridges in various sections, among them being the Bellefontaine and the Leavenworth bridges over the Mississippi. In 1895 he was appointed a civilian member of the first Nicaragua Canal Commission; the report of this Commission led to the abandonment of the Maritime Canal Company's Route. Dr. Noble was also a prominent member of the Isthmian Canal Commission of 1899, and he rendered important service as a member of the United States Deep Waterways Commission in 1897. Following his activities on these commissions, he was engaged in private practice in a number of important works. From January, 1902, to 1910, he was Chief Engineer of the East River Division of the Pennsylvania Tunnel and Terminal R. R., during the period of the construction of the four tunnels across the East River and of the Terminal Station. In 1905 Dr. Noble was appointed by President Roosevelt a member of the International Board of Consulting Engineers on the Panama Canal. From May, 1909, he was engaged in general consulting practice with the firm of Noble and Woodard, and also acted as consulting engineer to the Board of Water Supply of the City of New York.

His connection with learned societies included presidency of the American Society of Civil Engineers and of the Western Society of Engineers; it also embraced membership of the Institution of Civil Engineers of Great Britain, etc. In 1895 Dr. Noble received the honorary degree of LL.D. from Michigan University. In 1910 he was presented with the John Fritz Medal for notable achievements in civil engineering. He was awarded the Elliott Cresson Medal, the highest recognition in the gift of The Franklin Institute, in 1912, and in the following year he was elected to membership in the Institute, and was also from this time one of the associate editors of its Journal.

George E. Kirkpatrick, general manager of the Girard Estate for the Board of Directors of City Trusts of the City of Philadelphia, was born in Philadelphia in 1858. He became affiliated with the Girard Estate in 1878, soon being made superintendent, then manager, and finally general manager, which position he held at the time of his death. His father also occupied the latter position for a number of years, and was at one time a professor in the Philadelphia High School.

Mr. Kirkpatrick was for some years a director of the Commonwealth Title Insurance and Trust Company. He was a member of the Geographical Society, a director of the Wanamaker Institute of Industry, treasurer of the Alumni Society of the Central High School, and Secretary of the Girard Water Company.

He was elected to membership in The Franklin Institute in 1889, and from 1911 to his death he was a member of its Board of Managers. His connection with the Institute was chiefly in the administration of the John Scott Medal Fund, from the income of which awards and premiums are given by the Board of Directors of City Trusts on the recommendation of the Institute.



Geo. O. Simpson

LIBRARY NOTES.

Purchases.

BARKER, A. H.—Barker on heating; theory and practice of heating and ventilation. 1913.
BLACKWOOD, WILLIAM.—Calico engraving: a practical text-book. 1913.
BRAME, J. S. S.—Fuels—solid, liquid and gaseous. 1914.
CROSBY and FISKE.—Handbook of fire protection. 1914.
DICKINSON, H. W.—Robert Fulton, engineer and artist, his life and works. 1913.
FRENCH, J. W., ed.—Modern power generators. 2 vols. 1908.
GERLAND, ERNST.—Geschichte der Physik. 1913.
HALL, JOHN HOWE.—The steel foundry. 1914.
HAZEN, ALLEN.—Clean water and how to get it. 1914.
Industrial Arts Index.—Vol. 1. 1913.
JACKSON, WALTER.—Electric car maintenance. 1914.
KÄHLER, KARL.—Luftelektrizität. 1913.
London Chemical Society.—Progress of chemistry. Annual Report, vol. 10. 1913.
U. S. War Dept., Engineer Corps.—Engineer field manual. Pts. 1–4. 1912.
WALKER, G. W.—Modern seismology. 1913.
WOOD, JOHN K.—Chemistry of dyeing. 1913.
WREN, HENRY.—Organometallic compounds of zinc and magnesium. 1913.

Gifts.

American Gas Institute, Proceedings, vol. 8, 1913. New York, 1914. (From the Institute.)
American Institute of Electrical Engineers, Transactions, vols. 28–31, 1909–1912. New York, 1909–1912. (From Dr. R. B. Owens.)
American Mining Congress, Report of Proceedings, 1913. Denver, 1914. (From the Congress.)
Baldwin Locomotive Works, Record No. 76. Philadelphia, 1913. (From the Works.)
Bowser, S. F. & Co., Oil Filtration. Fort Wayne, Ind., no date. (From the Company.)
Brooklyn Institute of Arts and Sciences, 23rd to 25th Year-book, 1910–1912. Brooklyn, 1910–1912. (From the Institute.)
Canada Board of Railway Commissioners, 8th annual report, 1913. Ottawa, 1914. (From the Commissioners.)
Cause of business depressions, by Hugo Bilgram and Louis Edward Levy. Philadelphia, 1914. (From the Authors.)
Chart Atlas of Complex Hyperbolic and Circular Functions, by A. E. Kennelly. Cambridge, 1914. (From the Author.)
Concord Water Department, 42nd Annual Report. Concord, N. H., 1914. (From the Department.)
Connecticut Public Utilities Commission, 2nd Annual Report, 1913. Hartford, 1914. (From the Commission.)

Elements of trigonometry, by Herbert C. Whitaker. New York, 1898. (From the Author.)

Finland Patent Office, Arbetsstatistik XVI, Undersökning angaende Sägindustrin. Helsingfors, 1914. (From the Office.)

George Washington University, Catalogue, March, 1914. Washington, D. C., 1914. (From the University.)

Kolonial Instituut, Derde Jaarverslag, 1913. Amsterdam, no date. (From the Institute.)

Michigan State Board of Health, 40th Annual Report, 1912. Lansing, 1914. (From the Board.)

National Association of Cotton Manufacturers, Transactions No. 95. Boston, 1914. (From the Association.)

New Bedford Water Board, Report, 1913. New Bedford, Mass., 1914. (From the Board.)

New York Central and Hudson River Railroad Co., Report for 1913. New York, no date. (From the Company.)

New York City Public Service Commission for the First District, Regulation of Public Service Companies in Great Britain. New York, 1914. (From the Commission.)

Oberlin College, Annual Catalogue, 1913–14. Oberlin, Ohio, 1914. (From the College.)

Ontario Department of Agriculture Entomological Society, 44th Annual Report; Fruit Growers' Association, 45th Annual Report; Horticultural Societies, 8th Annual Report. Toronto, 1914. (From the Department.)

Pennsylvania Department of Fisheries Report, 1912; Sinking Fund Commissioners Report, 1913; Secretary of Internal Affairs, Part 3, Report, 1912; and Department of Mines, Part 2, Report, 1912. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Railroad Company, 67th Annual Report, 1913, and 59th Annual Report of The Northern Central Railway Co. Philadelphia, 1914. (From the Company.)

Pennsylvania State Librarian, Report of Librarian, 1913. Harrisburg, 1914. (From the Librarian.)

Philadelphia Civil Service Commission, Annual Report, 1906–1912. Philadelphia, 1906–1912. (From the Commission.)

Providence Public Library, 36th Annual Report, 1913. Providence, Rhode Island, 1914. (From the Library.)

Railway Statistics of the United States for 1913. Chicago, 1914. (From Mr. Slason Thompson.)

Society for the Promotion of Engineering Education, Proceedings, 1910–1912. Ithaca, N. Y., 1911–1913. (From Dr. R. B. Owens.)

Study of North Appalachian Indian Pottery, by Christopher Wren. Wilkes-Barre, Pa., 1914. (From the Author.)

United States National Museum, Annual Report, 1913. Washington, D. C., 1914. (From the Museum.)

University of Colorado, Catalogue, 1913–1914. Boulder, 1914. (From the University.)

University of South Carolina, Catalogue, 1913–1914. Columbia, 1914. (From the University.)

Verein deutscher Eisenhüttenleute. Migliederverzeichnis, 1914. Düsseldorf, 1914. (From the Society.)

Wilmington Board of Park Commissioners, Report, 1913. Wilmington, Del., no date. (From the Commissioners.)

Wisconsin History Commission, Original Papers, No. 8. Madison. 1914. (From the Commission.)

Zeitschrift des Vereins der Deutschen Zucker-Industrie, General-Register, 1893–1912. Berlin, no date. (From the Society.)

Zoological Society, The Forty-second Annual Report. Philadelphia, 1914. (From the Society.)

BOOK NOTICES.

THE GAS LIGHT & COKE COMPANY, 1812–1912. An account of the progress of the Company from its incorporation by Royal Charter in the year 1812, to the present time. Published privately.

This attractive brochure of 92 pages, with 42 illustrations, constitutes a most important contribution to the history of Public Service corporations and to the history of the gas industry. Written in pleasing style, it describes the conditions existing in London when this first gas company was projected; reviews the early experiments in gas transmission; the propaganda for and birth of the Company; the criticisms, obstacles and misfortunes it encountered and surmounted; its absorption of rival companies which had been created because of its own pioneering work; the development at Beckton of the enormous factory wherein the by-products are remanufactured into a large variety of much sought products; and beginning so far back as 1841, the sharing of the profits with the employees, first by superannuation and sick funds and later by copartnership. It is a history which no student of economics, sociology, politics or industry can afford to remain unacquainted with. The statistics are most impressive, for in 1911 this single city gas company had a capital of nearly $145,000,000, employed 12,637 workmen, and sold over 25,000,000 thousand cubic feet of gas, while it collected from its automatic meters 231,736,536 pennies. Beginning with gas at $3.64 per thousand it was five years before a dividend was paid. Under the London Sliding Scale it sold gas in 1912 for 60 cents per thousand and made a handsome profit.

The centenary which this brochure celebrates has a special interest for the readers of this Journal and the members of the Institute. The origin of the celebration, held so successfully at the Institute on April 18th and 19th of 1912, is set forth in full by Walton Forstall in this Journal on page 627 for June, 1912, and this convocation led to the publication by the American Gas Institute of the volume of 174 pages entitled "Lectures delivered at the Centenary Celebration of the First Commercial Gas Company to sell Gas as an Illuminant." Many centenary celebrations were

also held by the several local sections of the American Chemical Society and by various organizations devoted to the gas industry. The *Illustriete Zeitung* of Leizig brought out its number for June 27, 1912, as *Technische Kulturbilder I: Gas-Jahrhundert-Nummer* with a 110-page supplement filled with illustrations, many of which are in color. And now, to complete the record, comes this brochure.

CHARLES E. MUNROE.

PUBLICATIONS RECEIVED.

Practical Iron Founding, by Joseph G. Horner. Fourth edition, thoroughly revised and enlarged. 409 pages, illustrations, plates, 12mo. London, Whittaker & Co., 1914. Price, 5 shillings.

The Synthetic Use of Metals in Organic Chemistry, by Arthur J. Hale. 169 pages, 12mo. Philadelphia, P. Blakiston's Son & Co., 1914. Price, $1.50.

Modern Steel Analysis. A selection of practical methods for the chemical analysis of steel, by J. A. Pickard. 128 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Co., 1914. Price, $1.25.

The Theory of Heat Radiation, by Dr. Max Planck. Authorized translation by Morton Masius. 225 pages, 12mo. Philadelphia, P. Blakiston's Son & Co., no date. Price, $2.00.

Biochemic Drug Assay Methods, with Special Reference to the Pharmacodynamic Standardization of Drugs, by Paul S. Pittenger. Edited by F. E. Stewart. 158 pages, illustrations, 12mo. Philadelphia. P. Blakiston's Son & Co., no date. Price, $1.50.

U. S. Bureau of Mines, Bulletin 67. Electric Furnaces for Making Iron and Steel, by Dorsey A. Lyon and Robert M. Keeney. 142 pages, illustrations, 8vo.

Technical Paper 68, Petroleum technology 15. Drilling Wells in Oklahoma by the Mud-laden Fluid Method, by A. G. Heggam and J. A. Pollard. 27 pages, illustrations, 8vo. Washington, Government Printing Office, 1914.

U. S. Department of Agriculture, Bulletin No. 93: The Temperature of the Honeybee Cluster in Winter, by E. F. Phillips, Ph.D. 16 pages, 8vo. Bulletin No. 103: Alum in Foods. 7 pages, 8vo. Bulletin 583: The Common Mole of the Eastern United States, by Theo. H. Scheffer. 10 pages, illustrations, 8vo. Washington, Government Printing Office, 1914.

Konstant auftretende secundäre Maxima und Minima in dem jährlichen Verlauf der meteorologischen Erscheinungen von Dr. E. van Rijckevorsel. Xter Teil. Separat Abzug aus: Koninklijk Nederlandsch Meteorologisch Instituut, No. 102. 23 pages, tables, plates, 8vo. Utrecht, Kemink & Zoon, 1914.

Eli Whitney Blake, Scientist and Inventor, by Henry T. Blake. 19 pages, portrait, 8vo. No place, no date.

The Engineers' Club of Dayton, General information, by-laws. 28 pages, 12mo. Dayton, Ohio, 1914.

National Association of Cotton Manufacturers, Programme and Papers; Annual Meeting, Boston, Mass., April 29 and 30, 1914. 17 pamphlets, 8vo. Boston, Association, 1914.

CURRENT TOPICS

Increasing Size of Steam Turbines. ANON. (*Sci. Amer.*, cx, No. 8, 155.)—An extraordinary development is taking place in the size of the individual unit in the field of steam turbines. A short time ago the *Scientific American* commented on the fact that a unit of 20,000 kilowatts had been built; yet during the past year one of this size and another turbine of 25,000 kilowatts have been constructed. It is stated that orders have been placed for four of 30,000 kilowatts and one of 35,000 kilowatts.

Linking Germany with her Colonies. ANON. (*Sci. Amer.*, cx, No. 12, 245.)—The German government is negotiating with Holland for permission to erect a wireless station on the island of Sumatra, Dutch East Indies. Such a station would be able to communicate on the one side with German East Africa and on the other with the Caroline Islands. If this plan succeeds, all the German colonies would be able to communicate with Berlin without making use of any cable. This would alleviate one of Germany's greatest grievances—that in communication with its colonies it is now dependent on Great Britain, which controls most of the cables.

Spring Suspension of Cycle-cars. ANON. (*Sci. Amer.* cx, No. 6, 113.)—Because of their light weight and narrow tread, the spring suspension of cycle-cars is a matter of the gravest importance. In this connection it is interesting to note that several engineers prominent in the automobile industry have offered their opinion that the cantilever type of spring seems best adapted for these light vehicles. This type possesses two cardinal advantages: It is less expensive to manufacture than many other types and in action eliminates practically all of the uncomfortable and often dangerous rebound that is a feature of nearly all other springs.

Surface Combustion. W. A. BONE. (*J. Gas Lighting*, cxxv, 572.)—Tests made with the 110-tube boiler at the Skinningrove iron works, after 5 months' run, showed that with a total evaporation of 5000 lbs. of water from and at 100° C. per hour the ratio of heat utilized to net heat supplied was 0.927 : 1, and that the physical properties of the tubes were not in any way impaired. In a test of a "Bonecourt" boiler recently installed in connection with Krupp's coking plant in the Ruhr district, Westphalia, an evaporation of 6750 lbs. of water per hour from and at 100° C. with an efficiency

ratio of 0.925 was realized. In regard to surface combustion in a bed of granular refractory material for melting metals, etc., it is stated that without regeneration it should be possible to obtain easily temperatures up to 2000° C. with coal gas, coke oven gas, or water gas, or about 1500° C. with low grade producer gas, such as Mond gas. Heating by means of diaphragms has been employed for more than a year for boiling and concentrating sugar solutions in a confectionery factory, the boiling being done in a copper pan over a circular diaphragm of 13 inches diameter. Some of the diaphragms have been in continuous day use for about one year, and the gas consumption is stated to be about one-half of that required when ordinary flame burners were used. Very rapid and efficient evaporation of liquids can be effected by using overhead diaphragms.

Use of Tar in the Basic Linings of Steel Furnaces. J. WAGNER. (*Rev. Mét.*, xi, 211.)—The constituents of coal tar which are beneficial in preparing furnace hearths of dolomite and tar are coal-tar acids, anthracene oils, and non-volatile pitch. The prejudicial constituents are light oils, naphthalene, free carbon in too high a proportion, and coal-tar bases. Tar intended for this purpose should yield, on fractionation, not more than 8 per cent. below 230° C., and not less than 30 per cent. between 230° C. and 350° C., and the loss on distillation should be about 3 per cent.

Metallurgical Industry in Russia. ANON. (*Amer. Mach.*, xl, No. 14, 588.)—The metallurgical industry of Russia, the principal centre of which is in Odessa, is showing increasing activity. Whether it will be able to cope with the growing demand for iron and steel is doubtful. In 1913 the production of pig iron amounted to 4,660,000 tons as against 3,500,000 in 1911. About 50,000 tons were imported; none was exported. The chief coal producing centre of Russia is in the Donetz basin, which provides 55 per cent. of the coal consumed in the country. Its output has risen from 12,000,000 tons in 1900 to 28,000,000 in 1913.

Magnalium for Pistons. ANON. (*Metal Ind.*, xii, No. 3, 104.)—Emil Grossman, a manufacturer of spark plugs, states that magnalium, an alloy of aluminum and magnesium, considerably lighter than aluminum, which has been used successfully for cylinders of gas engines, is now being tried for the manufacture of pistons for automobiles. For the past few years automobile engineers and designers have been giving a great deal of attention to the reduction of the weight of the various functioning parts of the gasoline motor. Ordinary cast iron used has a tensile strength of from 18,000 to 20,000 pounds per square inch, with a specific gravity of 7.5; while magnalium is stated to have a tensile strength of 23,000 pounds to the square inch, with a specific gravity only 2.5.

Absorption of Gases by Coal.—F. LEPRINCE-RINGUET. (*Comptes Rendus,* clviii, 573.)—Such gases as fire-damp, carbon dioxide, air, oxygen and methane, at pressures ranging from 0.25 to 80 atmospheres, were absorbed by coal to a much less extent than by charcoal, but in both cases the absorption was of the same general character; a state of equilibrium existed for each temperature and pressure, and the absorption markedly decreased as the temperature rose; the increased absorption with increased pressure was rapid at first but gradually tended to a limit. Equilibrium was reached very slowly, and in the case of carbon dioxide especially, evolution of the absorbed gas, however slowly effected, was spasmodic. Results of the same order of magnitude were obtained with coals of widely different composition and size of grain; they afforded no explanation of the large evolution of fire-damp observed in very gassy mines.

Active Nitrogen. E. TIEDE and E. DOMCKE. (*Ber.,* xlvii, 420.)—By means of a jointless glass apparatus in which Linde's' commercial nitrogen was passed over copper heated electrically to a temperature measured by a thermo-couple, it was shown that the afterglow was suppressed unless the nitrogen was purposely contaminated with oxygen, provided that the temperature and pressure were such that no dissociation of copper oxide took place. On raising the temperature beyond a limit depending on the pressure, the glow was restored. The phosphorescence of sulphur, iodine, sodium and thallium chloride, observed on heating them in nitrogen which has been subjected to the action of the electric discharge, and attributed by Strutt to the presence of active nitrogen, was similarly suppressed in the absence of oxygen.

The Commercial Importance of Esparto Grass. C. J. KOCH. (*Tropenpflanzer,* xviii, 59.)—The esparto plant grows best on mixed limestone and gravel soils; its natural region lies between 32° and 41° N. latitude, but it is capable of resisting considerable variations in temperature and is found at altitudes up to 3000 feet. The leaf ranges in length from 30 to 70 cm., attaining 1 m. under exceptional circumstances. It is pale green while growing but becomes yellow on drying; it rolls up when drying, attaining its cylindrical form at the ripening stage. About 200,000 tons of the grass are imported almost wholly by England; the quantity has remained stationary for 15 years, a decline from one source being balanced by increased importations from other sources. If the leaf is harvested before maturity the quality of the fibre is very inferior, yielding a semi-transparent paper. In most districts the use of the knife is forbidden; a tuft of grass requires 8 to 15 years before it becomes productive and may then be "pulled" annually for 30 to 50 years. The best time for pulling is the autumn; in most countries a close season is fixed by regulation during the earlier months of the year. The

harvested grass is stored and dried for a considerable time before packing for shipment; the hydraulic pressed bales weigh about 22½ lbs. per cubic foot. The majority of German paper makers are not interested in the grass, partly through unfamiliarity, partly owing to difficulties in procuring freights. Freights from Algiers and Oran run about 28/- per ton for Hamburg and 24/- for English ports. The area under esparto in Algeria is about 2,800,000 acres, of which three-fourths are in the department of Oran. Regulations as to season of cropping are in force, also certain zones are reserved as a protection against sand-drifts. Exports from Algeria were 100,788 tons in 1911 and 116,632 tons in 1912, average price 52/- per ton; exports from Tunisia were 50,197 tons in 1911, average price 57/- per ton. Increases from these countries in recent years have taken place at the expense of the Tripoli trade, now practically ruined by war and the scarcity of labor. The Spanish variety of esparto is still the most valuable, although high prices and careless industrial habits have led to wasteful methods of cropping. Exports have declined from about 60,000 tons in 1897 to 41,000 in 1912, but the fluctuations since 1904 show a fairly steady average; the price runs about 95/- per ton and has fallen from more than double this figure since 1883.

The Action of Formaldehyde on Wool. A. KANN. (*Färber-Zeit.*, xxv, 73.)—When treated with a 4 per cent. solution of formaldehyde wool becomes resistant to the action of alkali and loses its affinity for dye-stuffs. By the use of very weak formaldehyde solutions, 0.25 or as low as 0.1 per cent., the wool can be protected against the tendering action of alkali without losing its affinity for dye-stuffs. The reaction between wool and formaldehyde takes place with great ease in slightly alkaline solution and much less advantageously in acid or neutral solution. Wool thus treated can be dyed with sulphide dye-stuffs, it shrinks less on steaming and it can be scoured with caustic alkali, using very little soap. The treated wool reacts with nitrous acid just like untreated wool. This shows that wool does not contain an amino group, for such a group would have been rendered inactive by the formaldehyde. It is concluded that wool contains the imino group and the product of reaction with nitrous acid is a nitrosamine.

Grand Trunk-Pacific Railway nearing Completion. ANON. (*Sci. Amer.*, cix, No. 26, 487.)—This railway, which will give a new continuous route from the Atlantic to the Pacific, through Canada, has been so far completed that there remains only a gap of 220 miles to be built between Winnipeg and the Pacific Coast. On the mountain section over 600 miles of track have been completed, and the consulting engineer for the government states that as labor is abundant, the line will in all probability be finished by June 1, 1914.

Explosions in Liquid Air Plants. W. BRAMKAMP. (*Chem. Ind.*, xxxvii, 81.)—Two out of three explosions in plants for the fractional separation of oxygen from nitrogen were due to the unauthorized attempt to remove ice from the fractionating column by means of a blast-lamp and a red-hot spanner, respectively, the cork or silk lagging, saturated with oxygen, burned explosively. The third was ascribed to an accumulation in the receiver of the oxygen fraction of acetylene, partly as copper acetylide, which had escaped from a neighboring works. The author suggests as possible causes of explosions: stoppage of the tubes by solid argon; explosive vaporization of solid argon on warming; or accumulation of lubricant, or its decomposition products, or even methane from the air, which might become ignited on contact with ozone produced by the electrification by friction of the non-conducting liquid oxygen.

The Zeppelin Passenger Airship "Sachsen." ANON. (*Motorwagen*, xvi, 920.)—Aërial passenger service given by suitable airships is profitable providing a sufficient number of passengers are available. The Zeppelin Company alone has up to the present attained marked success in this field, chiefly owing to the large passenger accommodation of their vessels. The construction of the "Sachsen" is described and illustrated by half-tone; this is the 17th and latest vessel built at Frederickshaven on the Zeppelin rigid system. The "Sachsen" is 142 m. overall, 14.9 m. in diameter and 19,700 cubic metres in capacity. Eighteen gas cells in the balloon are separated by aluminum partitions; one or more cells may be emptied completely without compelling the descent of the vessel. The skeleton is covered with impregnated cotton material to reduce air resistance and the effect of the sun's rays, while making the whole fabric weatherproof. Below the balloon are suspended the two machine gondolas and the passenger cabin is between them. One 185-horsepower Maybach motor is placed in the fore, and two similar motors are placed in the aft gondola. Steering, ballast, and valve controls are assembled in the front gondola, from which the vessel is navigated. The fore motor drives a twin-blade propeller at 530 revolutions per minute. The stern motors each drive a 4-blade propeller at the same speed. The elevating and steering rudders are mounted in a common framework at the stern of the ship. Six vertical rudders enable the vessel to be turned on a radius of 350 m. Large horizontal fins extending above the rudder frame reduce any tendency to rolling to a minimum. A new feature is the addition of supplementary stabilizing surfaces, extending from the hull through the propeller frames at about 45° to the horizontal; these frames are designed to prevent the formation of eddy currents by the propellers. The multiplication of the driving and controlling equipments makes it possible to proceed after any breakdown at all likely to occur to any component of the equipment. Two motors drive the vessel at

65 km. per hour, and three motors drive it at 75 km. per hour (in still air). The gross lifting power of the "Sachsen" is 23,000 kg. at sea-level; the net or effective lifting power is about 6000 kg., according to altitude and temperature. The lifting power is reduced about 200 kg. per 80 m. of altitude and about 80 kg. per 1° C. rise in atmospheric temperature. From 1200 to 1500 kg. of oil and petrol are generally carried; this suffices for 10 or 12 hours' cruising under full power or 15 to 20 hours' cruising with two motors working. The distances traversed through the air are about 800 and 1000 km. respectively, but according to the direction of the wind, the distance travelled with regard to land or sea varies from 400 to 1500 km. A crew of nine is divided between the fore and aft machine rooms; the central cabin accommodates 25 persons and is luxuriously padded. A wireless equipment is carried. From May 3 to Sept. 30, 1913 (150 days) the "Sachsen" made on 110 days, 170 journeys, occupying 327 hours 30 minutes and totalling 15,584 km. (1600 miles). On these journeys, 3983 persons were carried at a fare usually between 100 and 200 marks each.

Algin. ANON. (*Sci. Amer.*, cx, No. 3, 61.)—A new product of seaweed is announced from Liverpool, called algin, which is used in the manufacture of non-inflammable cinematograph films and in the treatment of paper to make it water, flame and germ proof. Algin is said to be odorless.

Surveying with an Auto Truck. A party for the determination of the astronomic latitude of triangulation stations established by the Coast and Geodetic Survey and the United States Geological Survey, between Barstow, Texas, and the Pacific Ocean, has recently been formed under the direction of Mr. C. V. Hodgson, of the Coast and Geodetic Survey. Many of the stations are on mountains at an altitude of 10,000 feet and the results obtained will be used principally for geodetic purposes in the determination of the figure of the earth and the distribution of material in the earth's crust.

The means of transportation will be a 1½-ton automobile truck which was used successfully on similar work between Denver, Colo., and the Canadian border in the season of 1913. A similar truck had been employed also in 1912 on the 49th parallel boundary survey between the United States and Canada. The cost of the work during the season of 1913 is estimated as only one-half what it would have been if horses and wagons had been used for transportation. The saving in the coming season is expected to be even greater, as the country to be traversed is arid or semi-arid and the transportation of water and forage for stock would have been a difficult problem. It is expected that the work will continue until late in the autumn.

The conditions in which the truck was used were such as to require very frequent transportation of men and material between

widely separated points, and in a region remote from the ordinary means of communication.

In the experience with the truck in the year 1912 it was found that a field party and its equipment could cover easily from 75 to 100 miles in a day, over indifferent roads, including stops for gasoline, supplies, etc., *en route*. The machine will do the work of four horses and in one-fourth the time. It is equipped with solid rubber tires, dual behind, and with extra tanks for gasoline and water. The weight of the truck is about 6100 pounds and the weight of the equipment of all kinds carried, but excluding the weight of the three passengers, is about 2000 pounds, thus bringing the weight of the entire outfit to more than four tons. On the average, one gallon of gasoline was used for every 5.2 miles, and one gallon of oil for every 61 miles.

The chief limitation in the use of the truck for surveying arises from its weight, and a lighter truck would answer in some classes of work. Green poles were carried to place in front of the dual-tired rear wheels in passing through deep sand or mud, and heavy planks were carried for reinforcing the flooring of weak bridges. For use in mud or sand the dual tire possesses a great advantage over the single tire, but on the deeply rutted prairie roads the duals were found to wedge and bind in the ruts, so that it was necessary to take to the prairie alongside the road. For a skid chain a heavy, close-linked rather flat chain about 17 feet long was used. This was wound about six times around the rim and tires of each rear wheel and the ends fastened by heavy buckled straps by which the slack could be taken up.

Lead and Aluminum. ANON. (*Brass World*, x, 3, 84.)—Lead and aluminum do not alloy; if the two metals are melted together they separate upon cooling. At the bottom of the crucible lies the lead containing a trace of aluminum, and at the top lies the aluminum containing a very small amount of lead. The two metals adhere to one another when they have cooled and set, but with a distinct line of separation.

Instability of Gaseous Ions. R. D. KLEEMAN. (*Cambridge Phil. Soc. Proc.*, xvii, 263.)—The previously attained results are summarized, and then the results of further experiments are discussed, leading to these conclusions: (1) The period of life of an elementary ion or cluster varies largely with the nature of the gas, and is greatly modified by slight admixtures of other gases; (2) the period of life of a cluster in a gas at standard pressure may have a value lying between a few seconds and a small fraction of a second. The order of magnitude of the period of life of an elementary negative ion is about 1/100 that of a cluster. The various expressions obtained by physicists for the velocity of an ion through a gas, on the assumption

that it consists of an unchanging cluster of molecules, must therefore be regarded as merely useful empirical formulæ. The results also suggest a modification in the ordinary theory of ionisation by collision, as they indicate, not a current of elementary ions only, but also a current of clusters. The velocity of atomic ejection of an electron can have but little influence on the resulting ionisation by collision, as the electron will, on an average, undergo hundreds of collisions before reaching an electrode. But the direction of ejection relatively to that of the electric field will greatly affect the formation of clusters. A formula is developed for calculating the life period of a positive cluster, but the absence of data precludes the deduction of any definite conclusions from it, or even as to the life period of an elementary positive ion.

Plant for Producing Calcium Carbide and Nitrate. ANON. (*Sci. Amer.*, cx, No. 3, 61.)—An electro-chemical works, which ranks among the large Swedish plants of that type, has been installed near Johannesburg and is designed to turn out calcium carbide and nitrate by a new process invented by Engineer F. Carlson. It is stated that there are now running on this principle four 400-kilowatt furnaces using single-phase current, for the production of carbide. As to calcium nitrate, used as a fertilizer, there are six furnaces in use on the 3-phase system of 2600-kilowatt size. To secure the current the present plant demands, a large hydraulic plant is erected that cost over a million dollars and operates by power from the Ljungan stream.

Electric Conditions for the Change from the Arc- to the Spark-spectrum. P. LUDEWIG. (*Ann. d Physik.*, xlii, 3, 643.)—La Rosa has shown that in the light from the singing arc there is a change from the arc- to the spark-spectrum according to the relative magnitudes of the self-induction and capacity in the oscillating circuit. Wagner has investigated the subject further. The research shows that the spark-spectrum is not necessarily associated with the existence either of a high-potential or of electric oscillations. The spark-spectrum arises when the current curve consists of sudden jumps, with sufficiently long pauses lying between. The duration of the impulsive currents must be smaller than 10^{-4} second. Between the spark-spectrum and the arc-spectrum there exists a continuous series of intermediate spectra, and by increasing the duration of the current impulses the spectrum approaches nearer and nearer to the arc-spectrum. It thus appears that the arc- and spark-spectra take a special place in this series of spectra only because they happen to be, so far as is now known, the end members of the series. It is quite possible the series of spectra may be extended.

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